Key Factors Affecting Drift Deposition from UAV Pesticide Application

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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 last 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

Edge of Field (EOF) Adjustment Factor for UAV Applications

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

Both data sets considered in our canonical correlation analysis

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

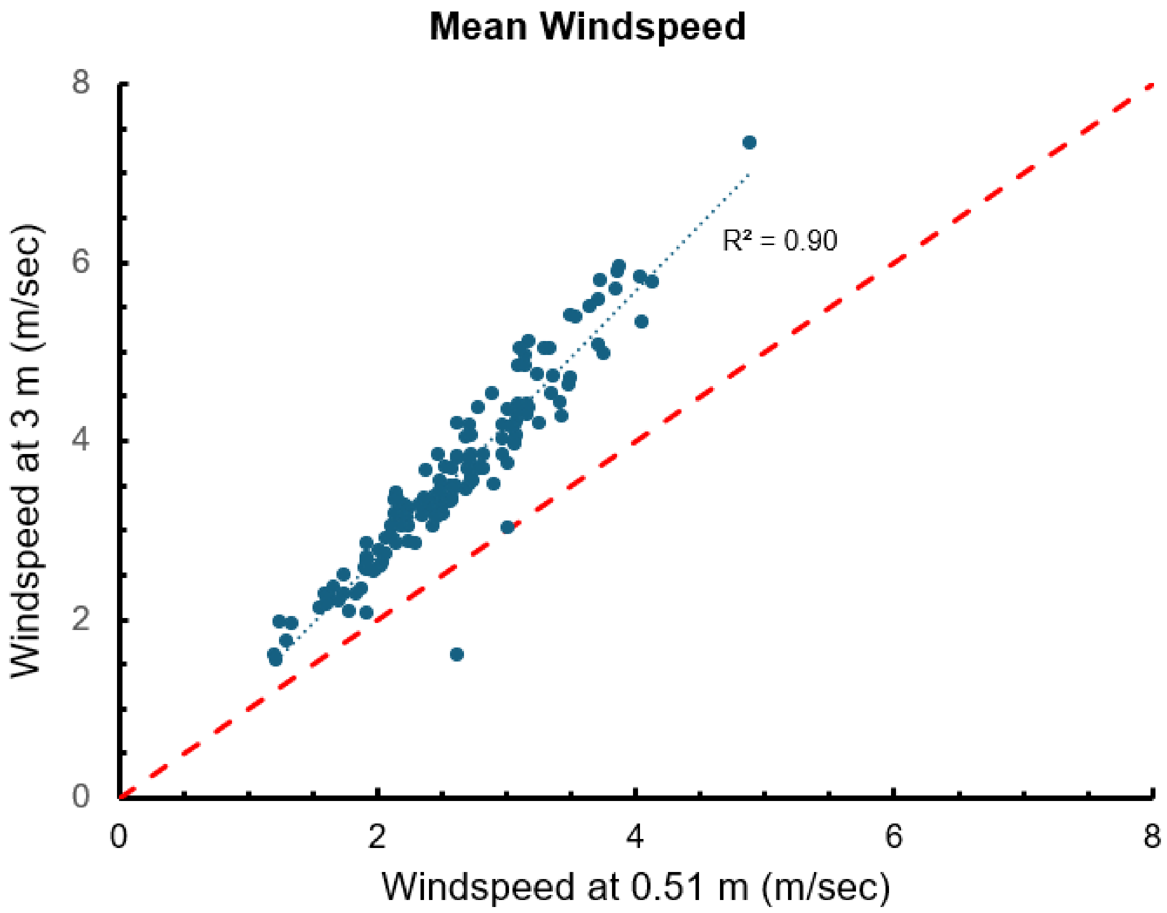
Analytical Approach

Analysis 1 – Principal Components Analysis (PCA)

- Characterize how meteorological conditions differed within and between study locations
- Determine whether meteorological conditions overlapped or were distinct between locations
- Original PCA data set reduced from 16 input variables to 10 input variables because of lack of variability and redundancy of windspeed variables at two heights
- Eliminated windspeed and direction variables at 3 m

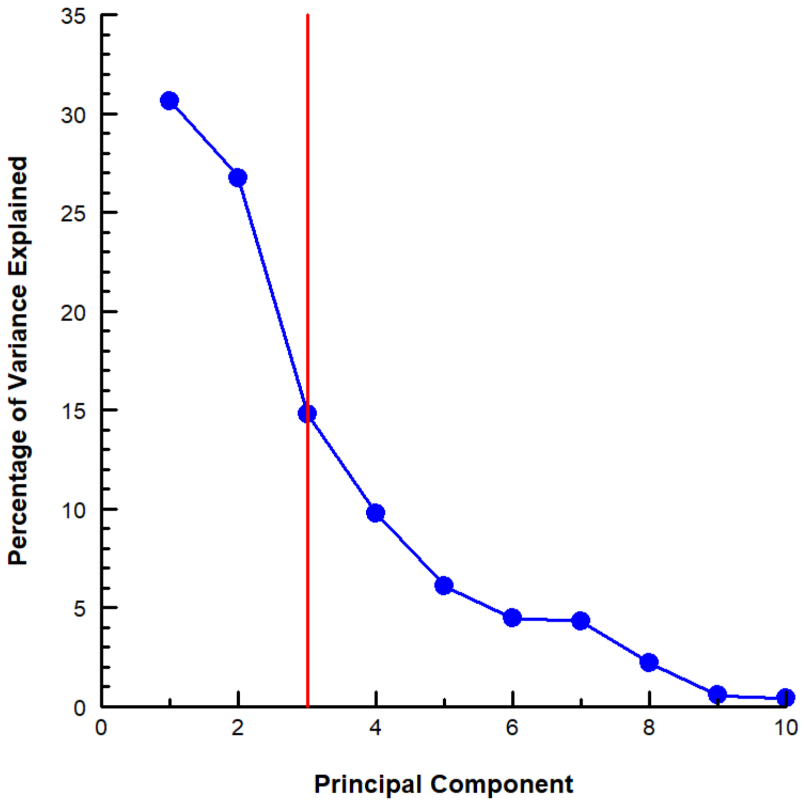
Analysis 2 – Canonical Correlation Analysis (CCA)

- Quantify relative importance of application method, spray quality, and meteorology on downwind drift
- Predictor variables included estimated drift deposition at 3, 10, and 100 m
- Two data sets: Unadjusted edge of field (EOF), adjusted EOF

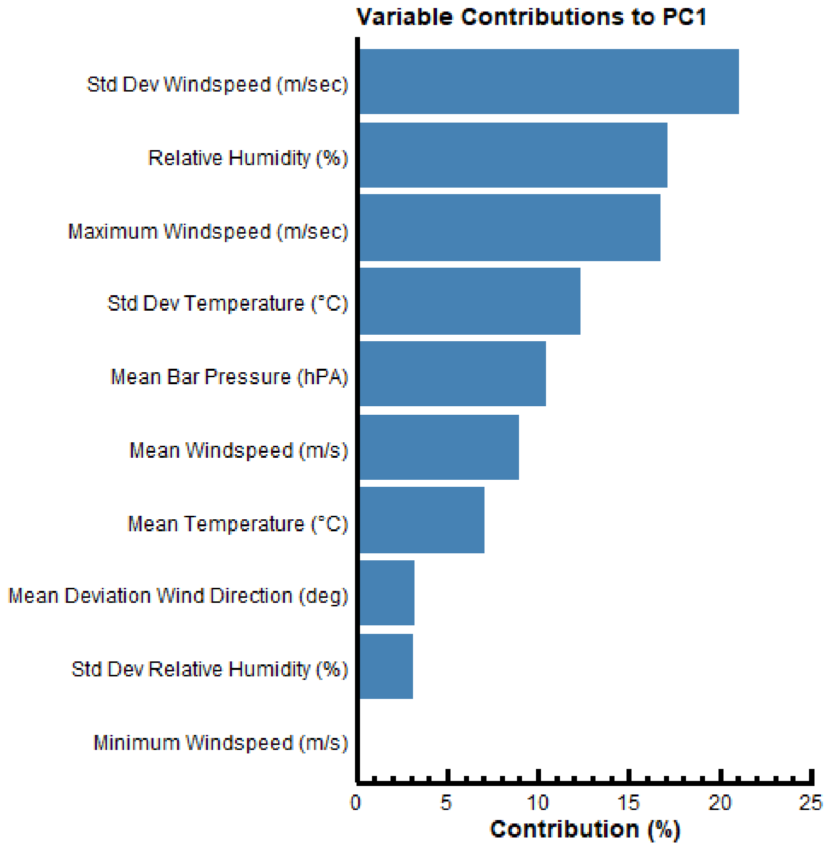


PCA — Meteorological Variables and Dimensionality Reduction

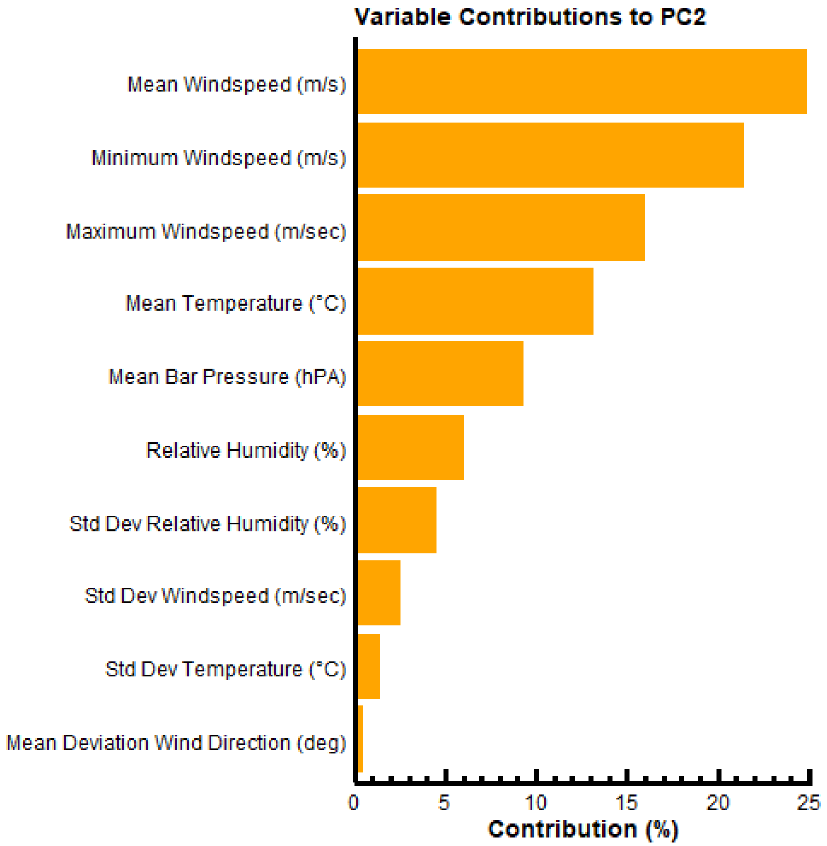
72% Variation Explained in First 3 Principal Components



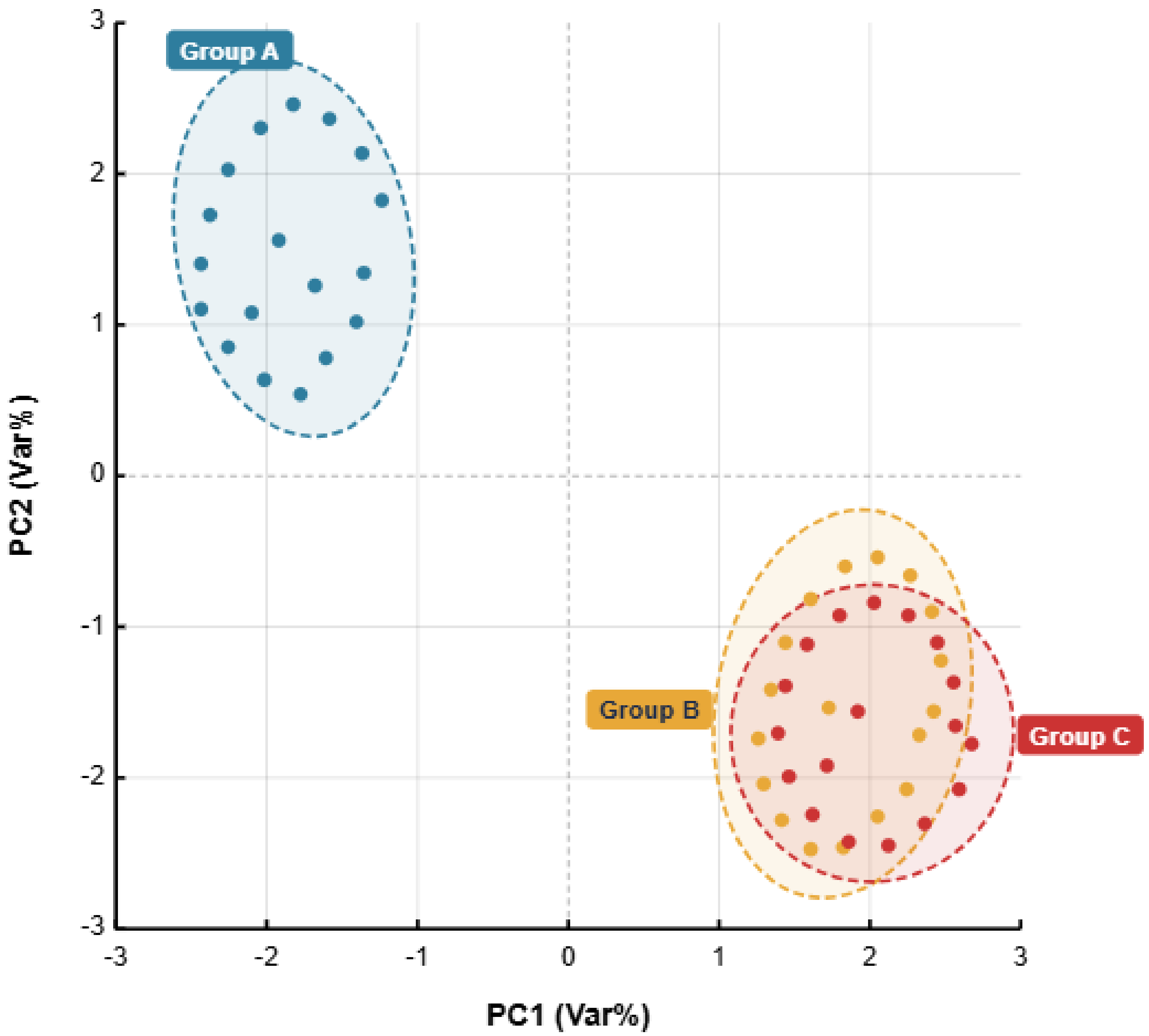
Gustiness and Humidity



Sustained Windspeed



95%ile Confidence Ellipses



Confidence ellipse encloses region expected to contain 95% of future observations drawn from the same multivariate normal distribution

Provides visual summary of within and between group variation

Large group ellipse → high within group variation for meteorological conditions

Non-overlapping group ellipses (e.g., A vs B) → strong evidence that locations had different meteorological conditions

High overlap of group ellipses (e.g., B vs C) → strong evidence that locations had similar meteorological conditions

PCA — Location Overlap Reveals Similar Meteorological Regimes

95% confidence ellipses determined for each location using trial scores (n=18)

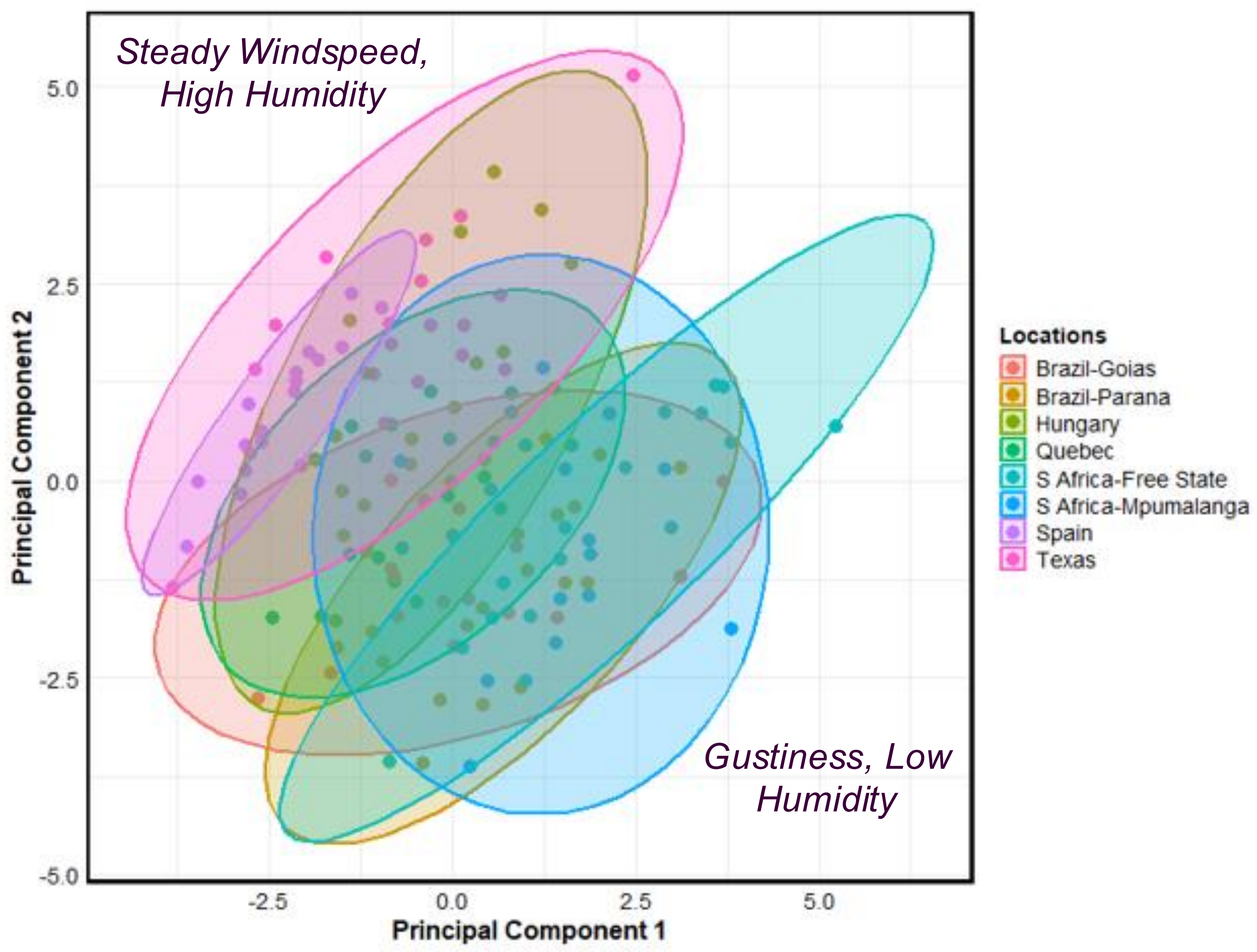
Considerable overlap of location ellipses

Within location variability as large as between location variability

Indicates similar meteorological conditions between locations

Partial separation between windy/high humidity locations (Texas, Spain) and gusty/low humidity locations (S. Africa–FS, Brazil–Paraná, Brazil–Goiás)

Lack of separation between locations likely due to tight windspeed window (2-5 m/second) when trials were conducted



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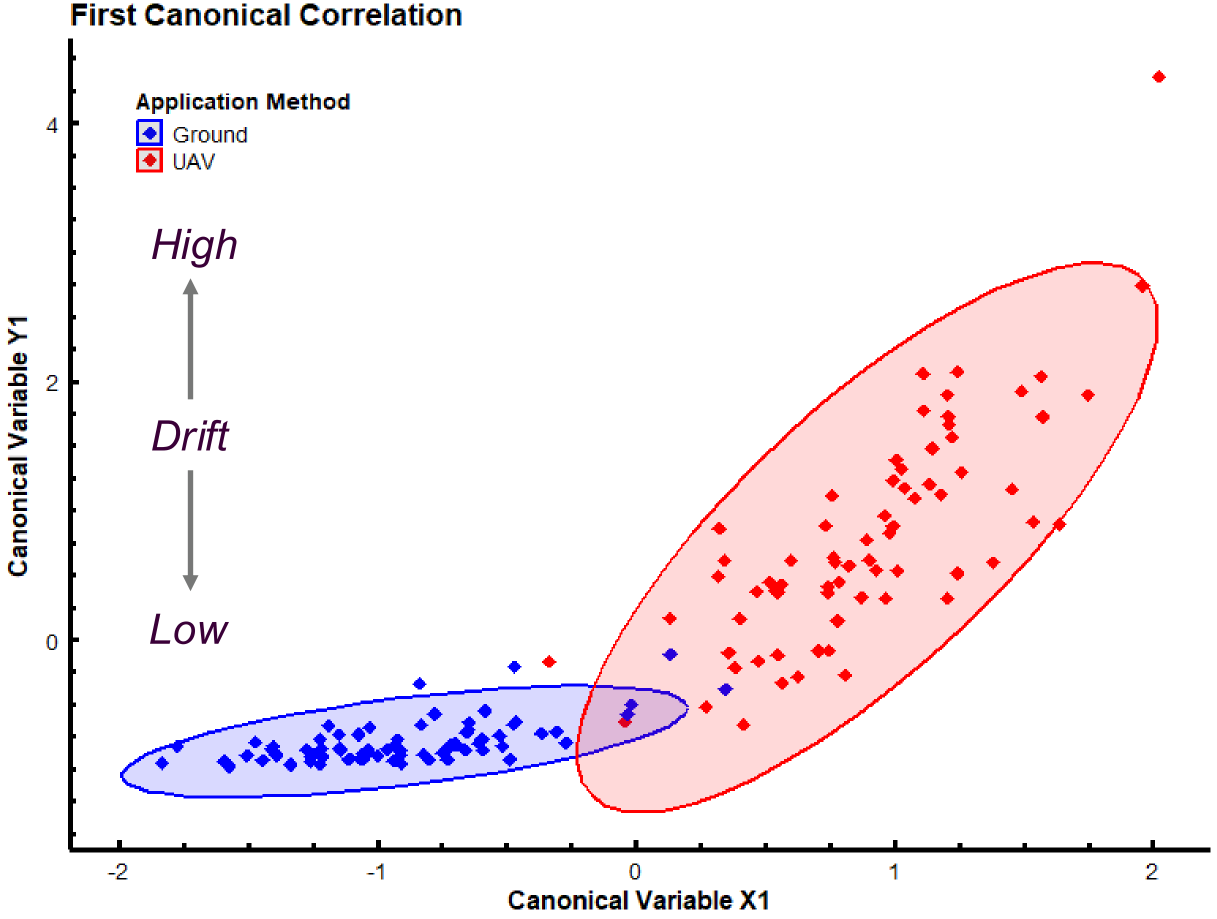
CCA — Application Method Dominated Drift Prediction (Unadjusted EOF)

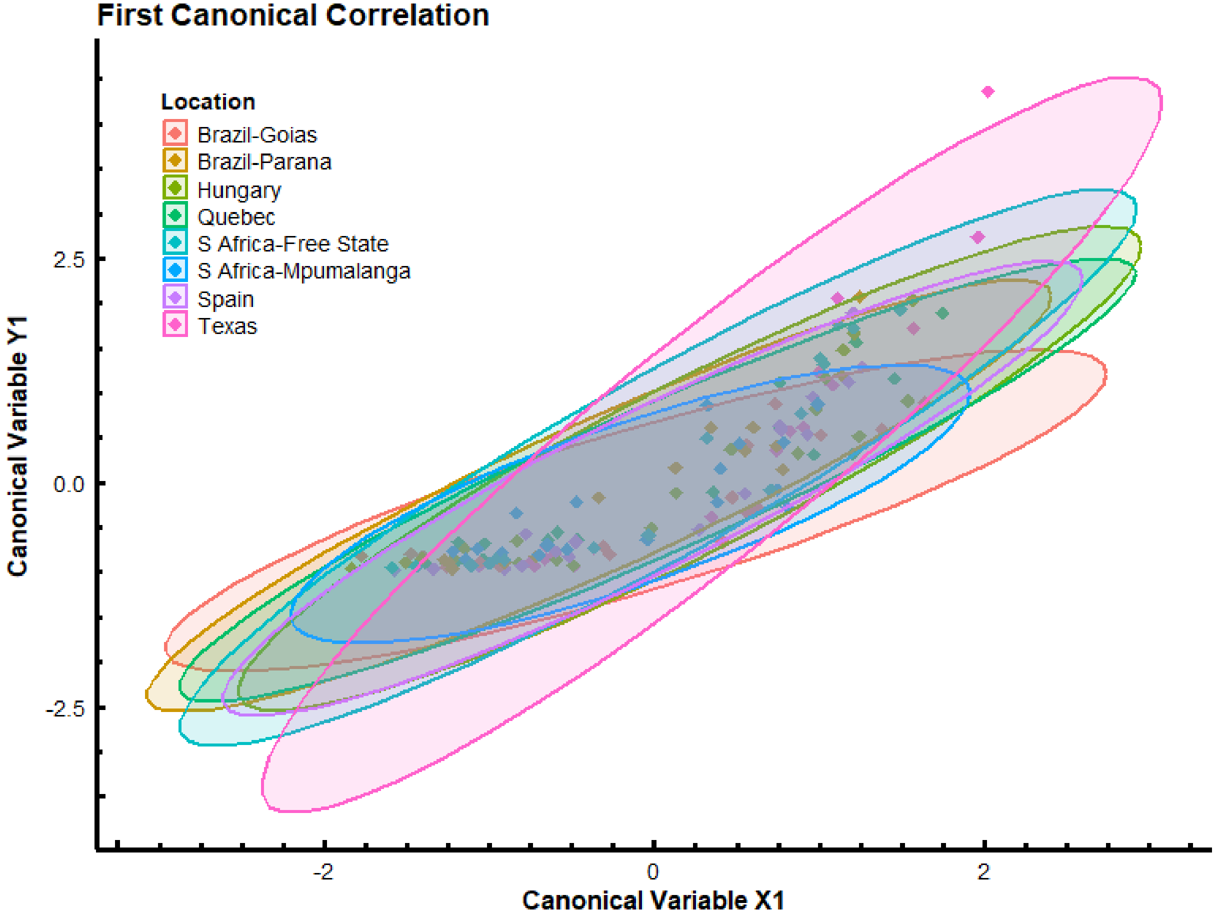
95% Application Method Ellipses

- Clear separation — UAV consistently produced greater downwind drift than ground



95% Location Ellipses

- Location ellipses completely overlapping — study location does not explain drift variation



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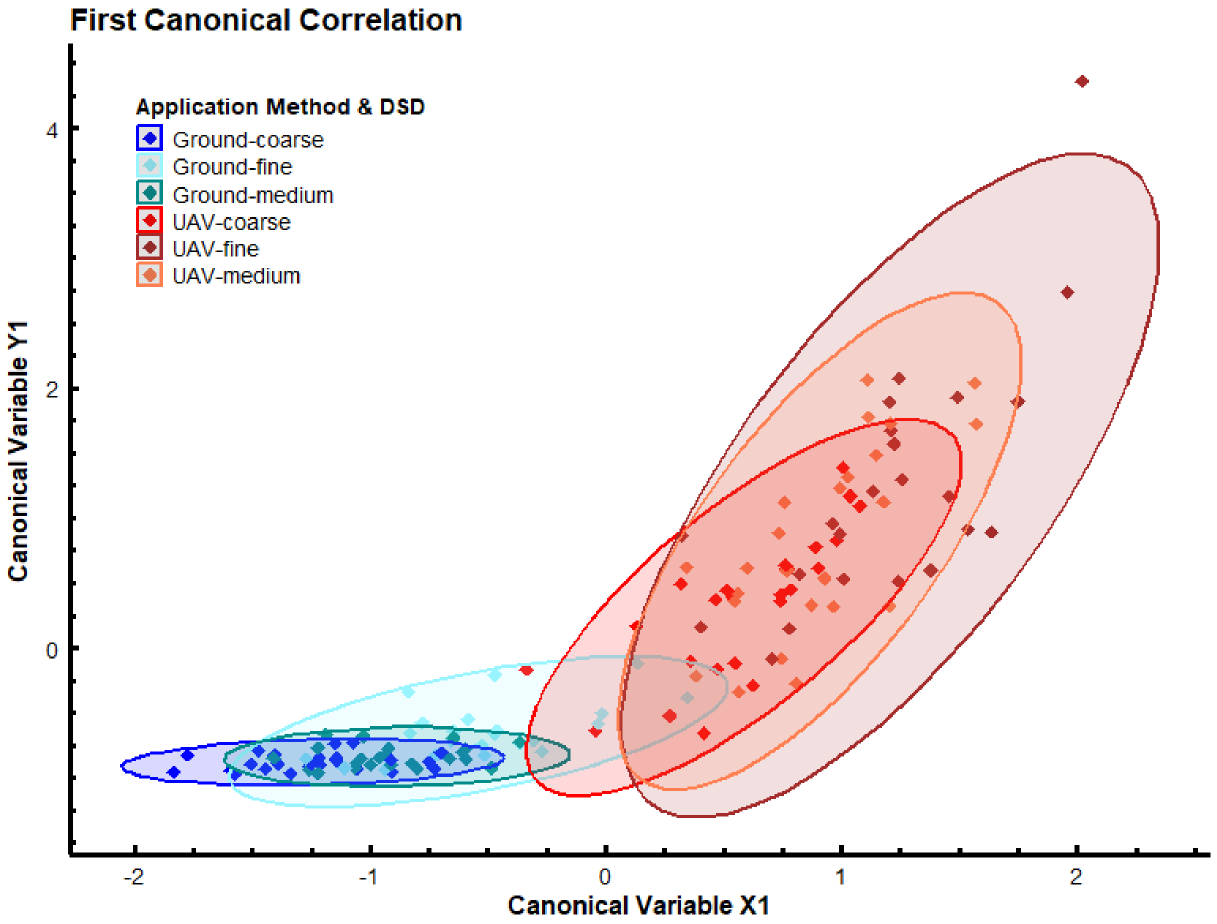
CCA — Spray Quality Less Important than Application Method

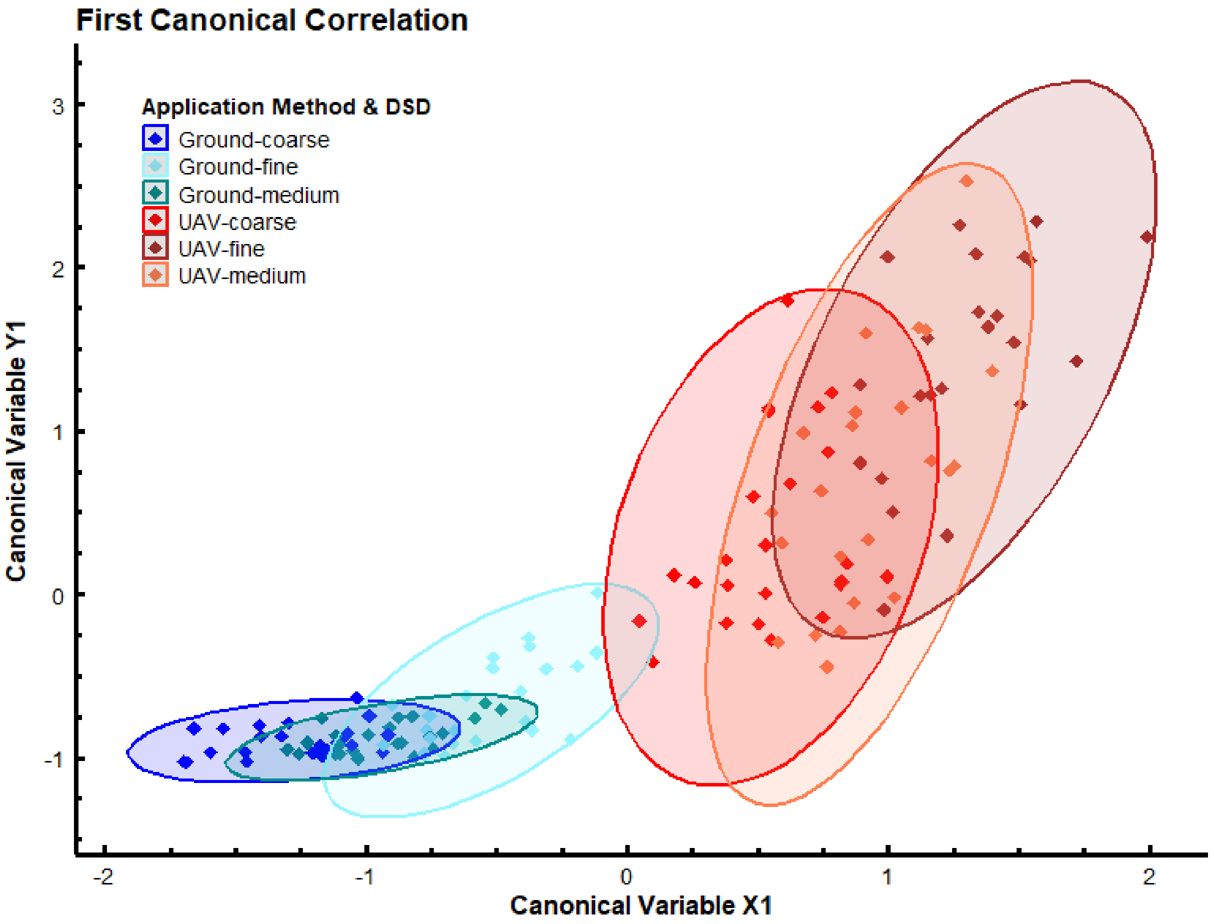
95% Ellipses (Unadjusted EOF)

- Drift hierarchy: Fine > Medium > Coarse — consistent across all analyses but with overlap within each application method



95% Ellipses (Adjusted EOF)

- Similar to unadjusted EOF results but slightly better separation between spray qualities



Conclusions

UAV applications require separate drift management standards from ground applications

Coarser droplet sizes reduces drift deposition

Meteorological constraints (e.g., maximum wind speed) limited variability between locations

Global consistency across 8 locations strengthens confidence in the generalizability of results

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Thank you.

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