Definition of swath width and the associated application rate for OTM studies, and the effects of different application settings on swath

Unmanned Aerial Pesticide Application System Task Force (UAPASTF)

Jane Bonds Bonds Consulting Group LLC.
Naresh Pai Bayer U.S. - Crop Science

UAPASTF core mission is to supply regulatory data to inform the potential use of UASS

- OECD Working Party on Pesticides (WPP), OECD Drone Sub-Group: State of the knowledge
- CropLife America: Early indications for equivalency of uncrewed aerial spray systems with conventional application techniques
- UAPASTF: The ecological and environmental exposure (EEE)
  - Update the off-site movement database developed for CropLife America (CLA) Drone Working Group (DWG).
  - Refine the quality criteria for UASS OTM studies to have reliable exposure estimates suitable for use in model validation.

This work is not in isolation it builds on multiple years of research

In the race for productivity, are we losing sight of dose?

Platforms are becoming larger, faster, and more reliable, with fewer limitations from payload and pump capacity etc.

Applicators increasingly want higher speeds, and productivity comparable with crewed aircraft

Putting the pressure on increasing swath

Which means we are likely under dosing, and uniformity worsens

The role of a sprayer is to deliver the correct dose in an appropriate form

The unresolved problem is measuring the dose-bearing swath

How percent cover measures effect the swath width compared to volume, considering OTM studies are aiming for a form of mass balance

How speed, altitude, wind heading, wake interaction, nozzle configuration, and droplet size alter the deposition profile

How crosswind shifts the deposited mass away from the flightline

Why both effective width and wind-driven offset are needed for accurate in field targeting important for OTM studies

Steps to appropriately measure the volume applied.

Initial flow rate check aiming for less than 5% difference between nozzles (ISO)

Only turn on the spray when the aircraft is at speed

Measure the distance and the time the spray was on, have manual checks of speed and distance

Measure tank volume, the volume applied

We can measure flow and speed
Swath is not so simple

Spray uniformity within the swath

- Uniformity is poor due to the uncertain nozzle positioning, slow forward speeds, and interacting rotor wakes all produce complexity in swath
- The CV is often higher than 60%
- Meaning uniformity of qualitative measures cannot be used as the metric for flight line separation
- The dose to the target area will be the required metric for determining swath width
- And dose comes from volume measures not percent cover

101 on spray geometry **volume**

If you half the diameter you get 8 x the number of drops for the same volume

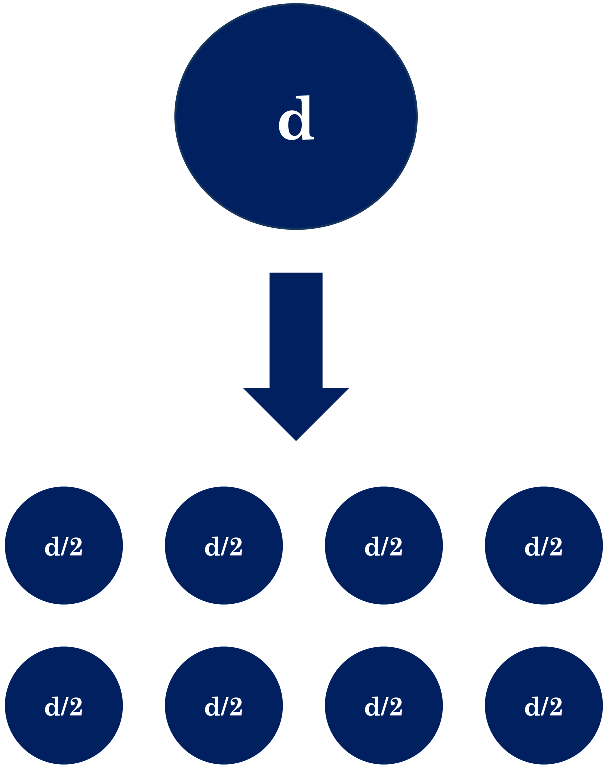
Droplet volume scales with diameter cubed

We try to improve coverage with small drops and reduce drift with big drops

Single drop d with volume V

$$V = \frac{\pi d^3}{6}$$

Single drop d with volume V



Half the diameter, total liquid volume is unchanged but is spread over 8 x d

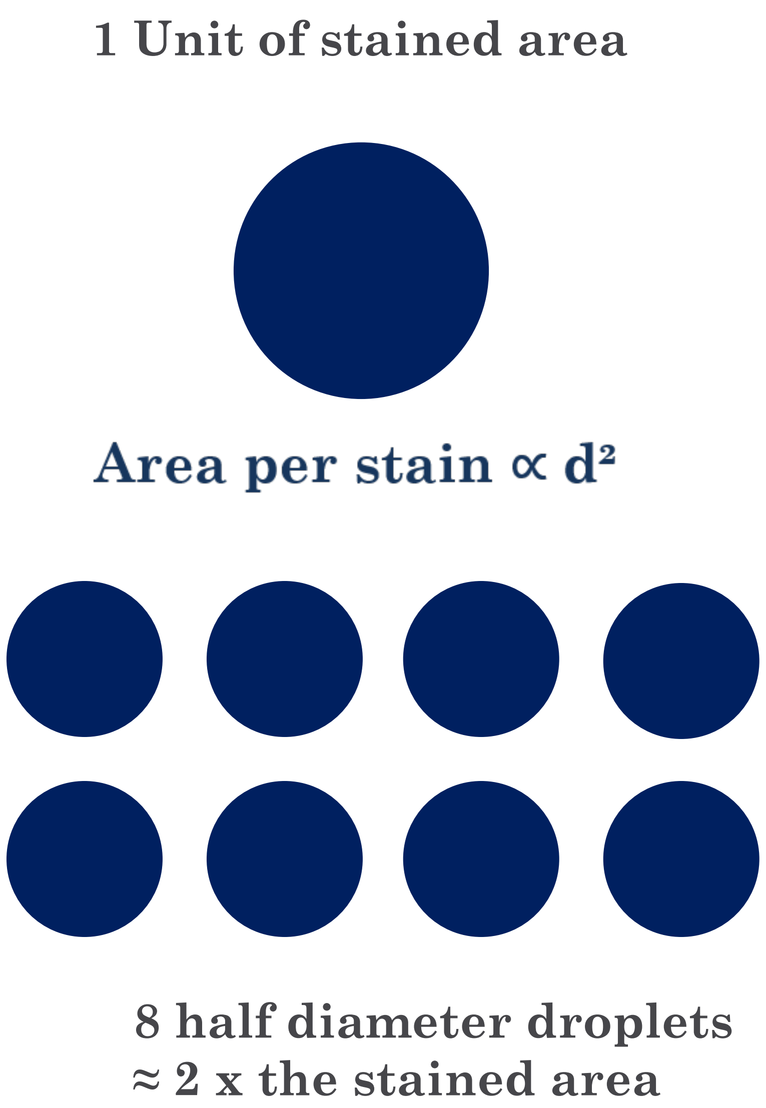
101 on spray geometry **coverage**

Assume stain diameter tracks with droplet diameter

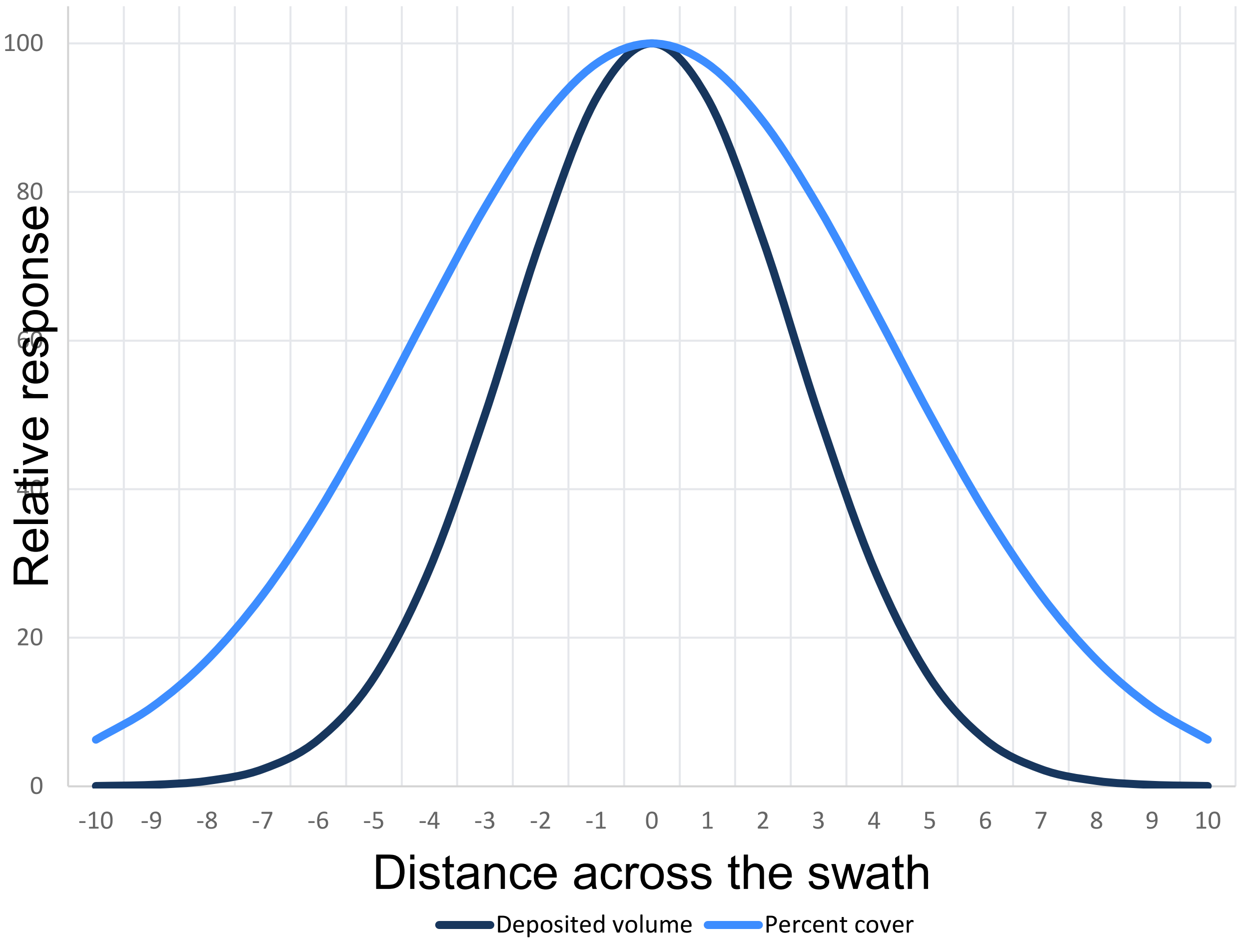
Half the diameter, roughly twice the visible coverage

8 droplets × ¼ stain area = 2× total stained area

Illustrative scaling: humidity, paper, formulation, spreading and overlap alter the exact precent coverage



Coverage can extend beyond the dose-bearing swath



When measuring a single swath

The center of the swath contains the highest density of large droplets, while the outer edges are composed almost entirely of low volume, fine droplets

With percent cover these smaller droplets have a much larger bearing than they would in a volumetric measure

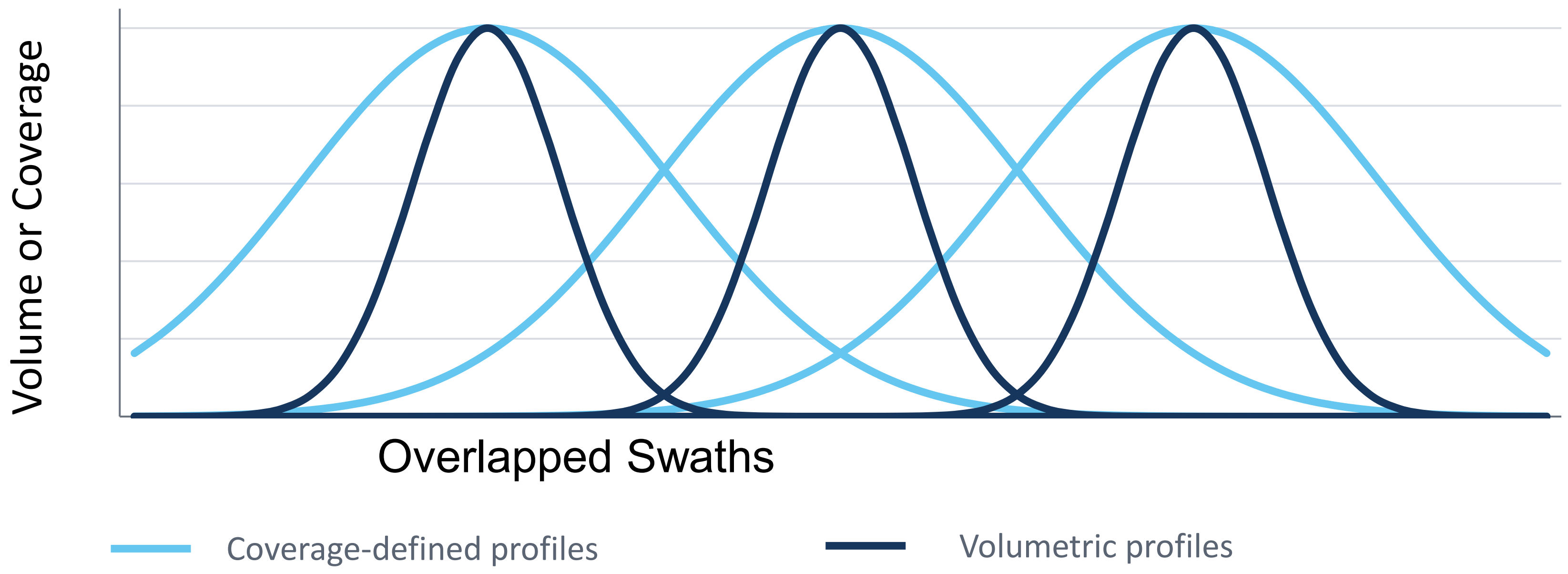
This will increase the size of the swath compared to if it were a volumetric measure

Overestimated swath width reduces volumetric overlap

Percent cover defines wider swaths, if coverage uniformity is your primary objective and the equipment then this works

Volume-bearing swaths however will be inherently narrower leading to under dosing reduced uniformity and streaks

OTM studies are designed to measure the distribution of the applied volume, a calibration with percent cover leads to a reduced total volume and uniformity



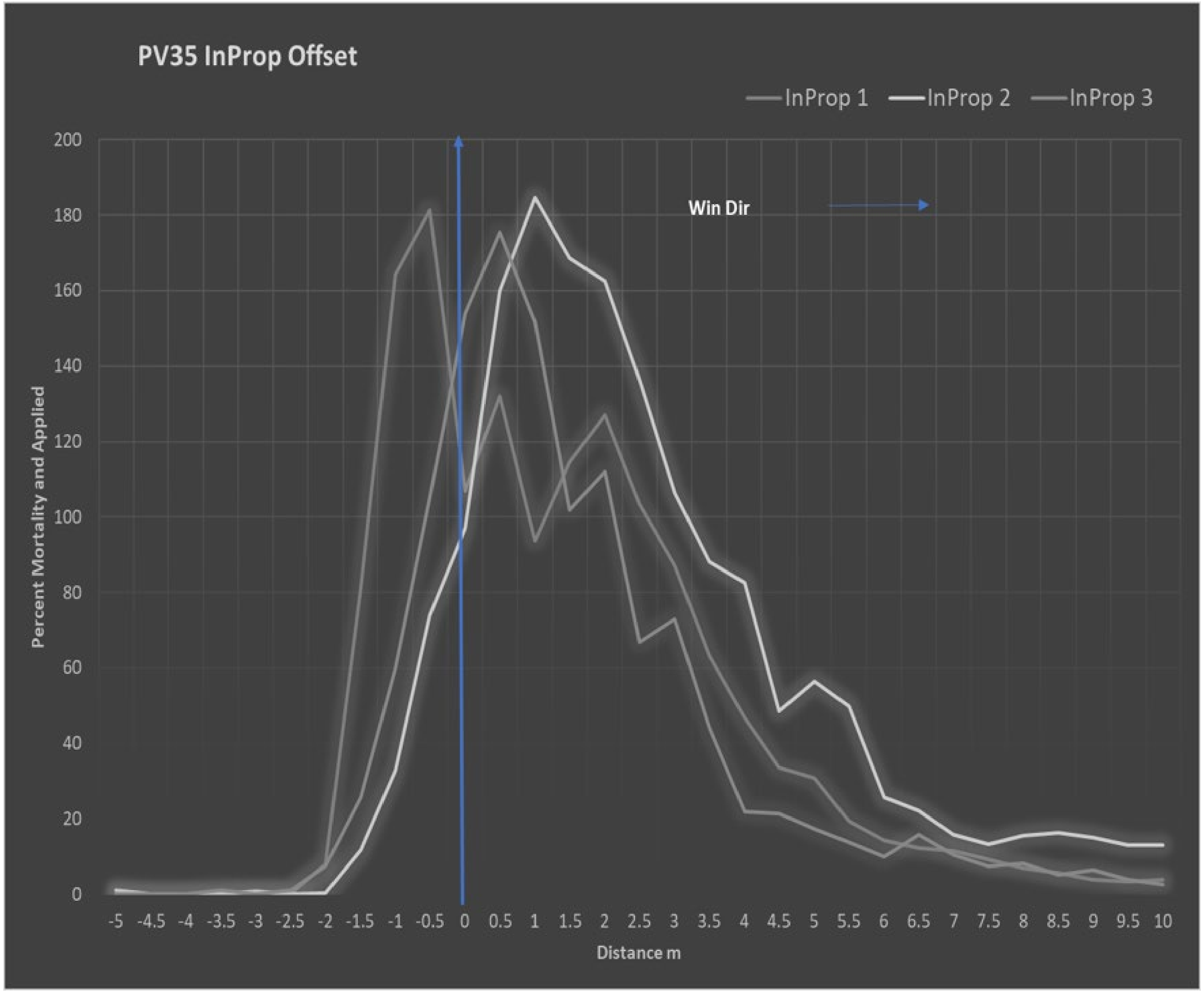
Nozzle Placement
The nozzle is the most important part of all sprayers

With conventional equipment we know where to locate the nozzle and how to space them for uniformity

Manned aircraft limit the boom width to 75% of the wingspan for fixed wing and 80% of the prop diameter for manned helicopters

Currently with UASS there is no science-based reasoning for the nozzle placement. They can be on booms within or without the accumulated prop diameter or attached directly under the rotor

In-prop placement concentrates spray within the propeller wake

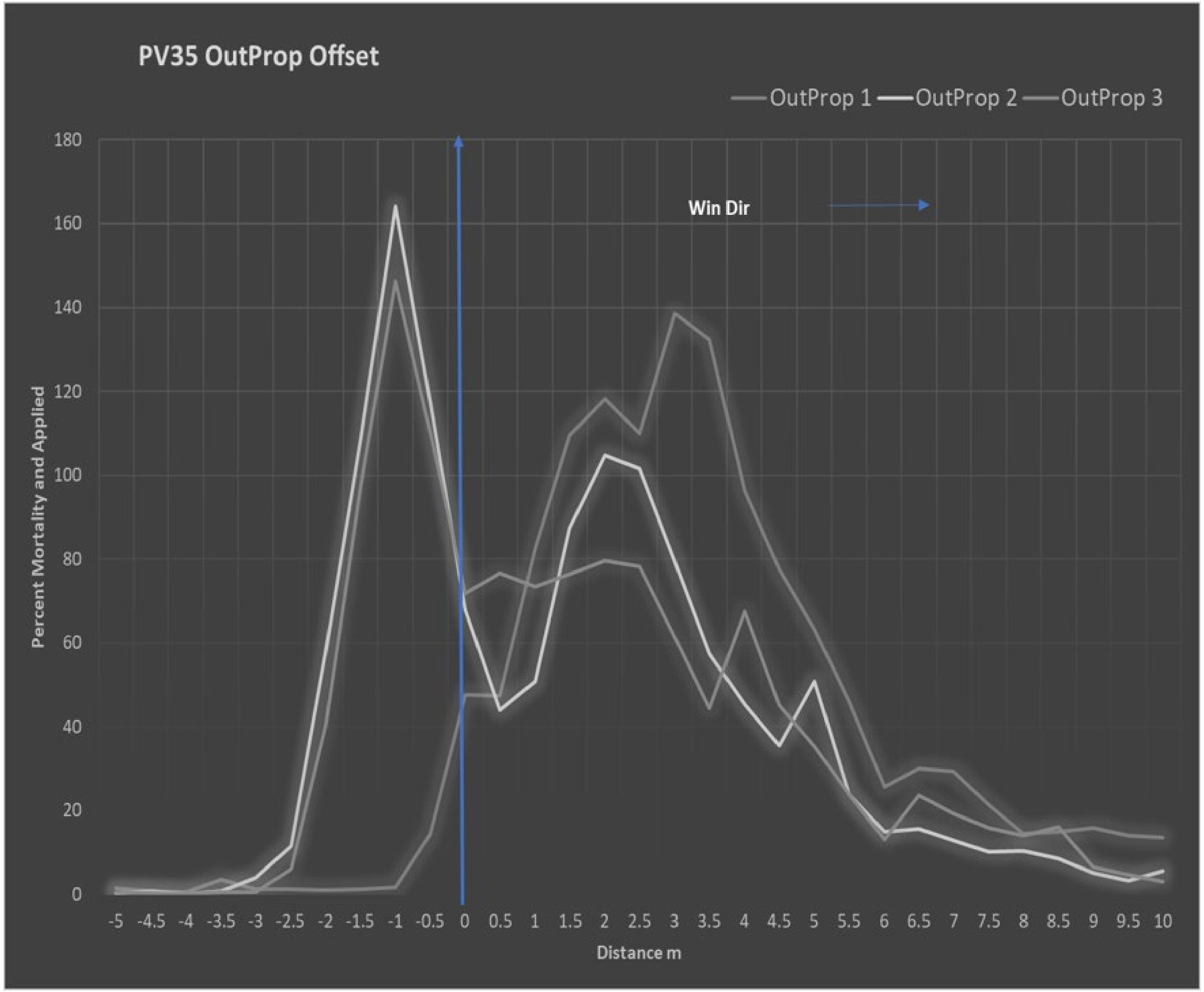


Conventional placement keeps all nozzles in the wake

- Nozzles are confined to 80% of propeller diameter, following conventional manned-aircraft guidance
- The three profiles cluster around the flightline and follow a similar downwind decay
- Peak magnitude varies, but most of the deposition remains concentrated close to the flightline

The propeller wake strongly governs the position and concentration of the spray

Outside-prop placement increases variability and downwind spread

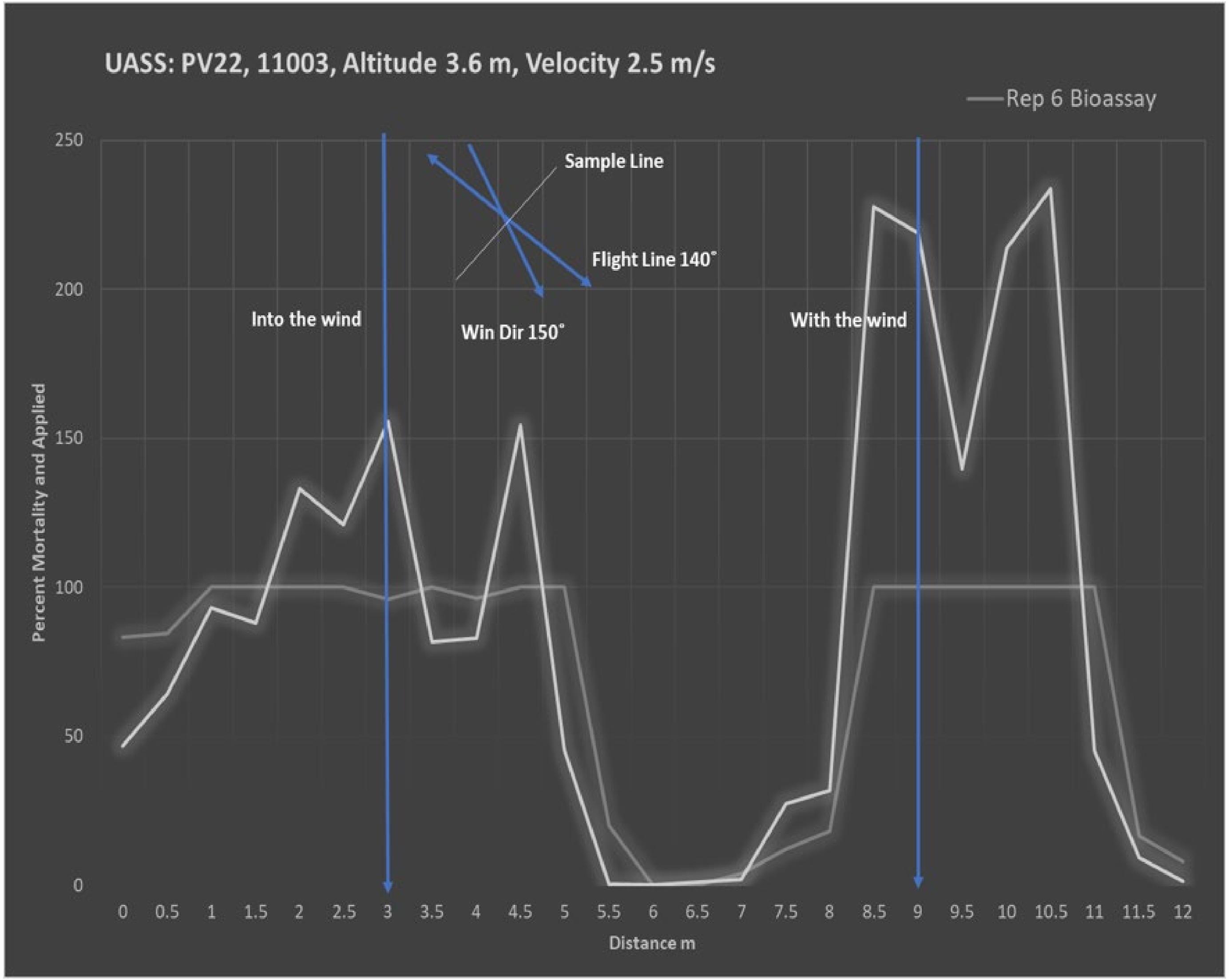


The outer nozzles are less controlled by the propeller wake

- The outer nozzle extends 10% beyond the propeller diameter and is less directly entrained in the central wake
- The deposition profiles are more variable and distinctly multi-peaked across the three replicates
- The extended downwind tail is consistent with greater off-target movement

The observed pattern indicates more drift and less uniform deposition

Wind heading effects significantly effects the spray placement

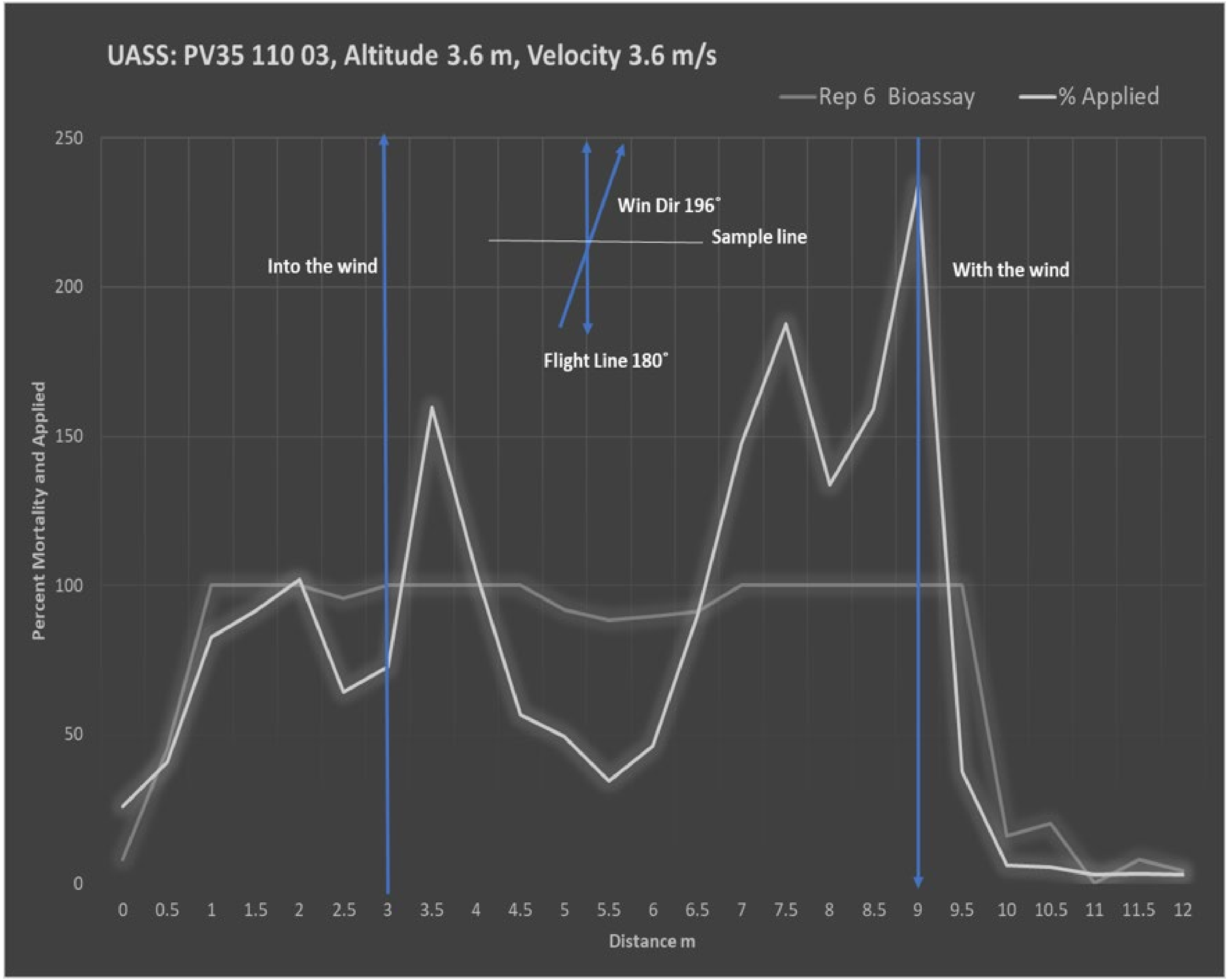


Wind heading separates the two passes at the low forward speed of 2.5 m/s

- The into-wind pass produces lower, wider more variable deposition volumes across the swath
- The with-wind swath is narrower with higher deposition volumes.
- Biological effect can be observed to drop off with the complete loss of deposition between the two swaths.

Wind heading affects both placement and the response measured on the ground

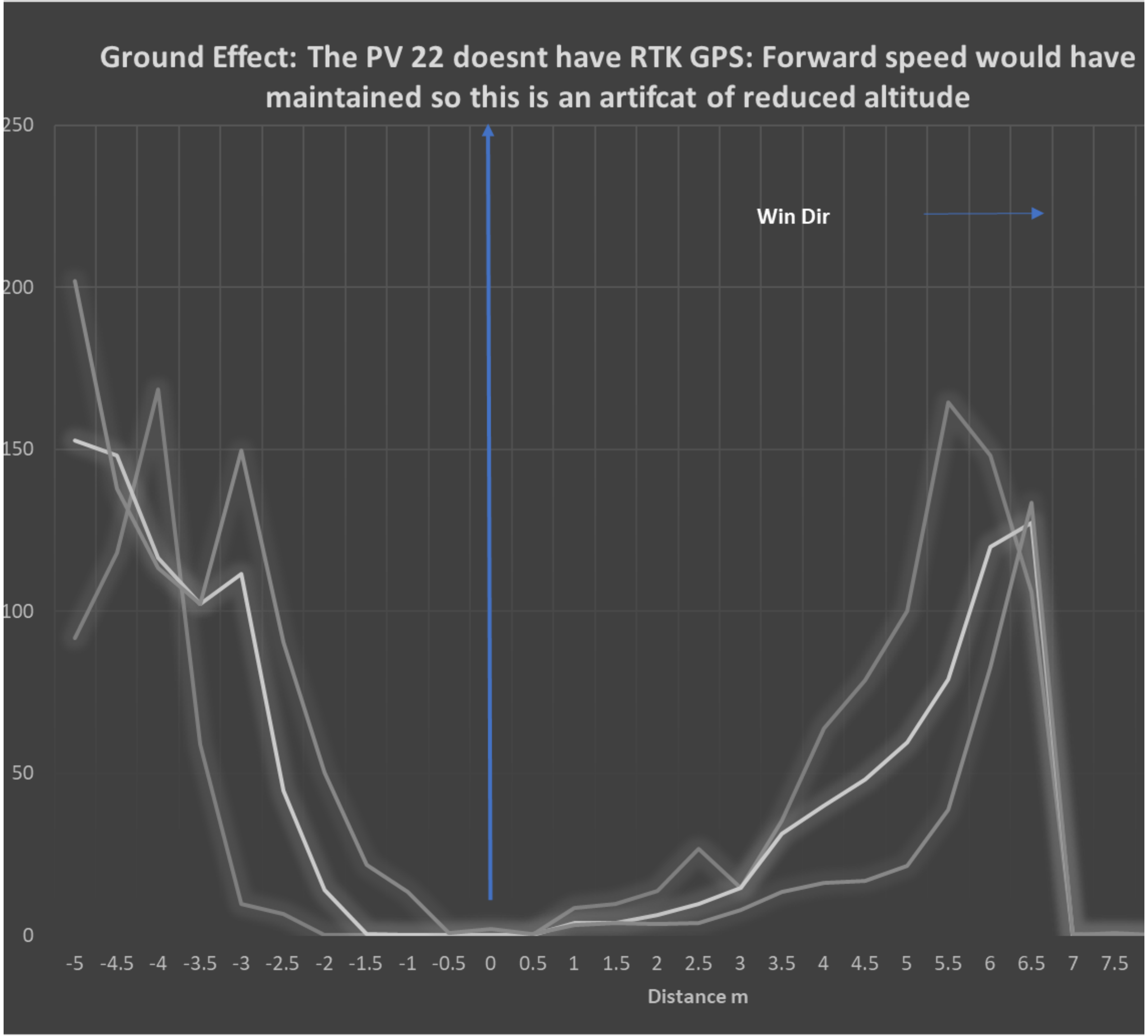
Higher forward speed redistributes the spray creates a larger swath



Higher forward speed 3.5 m/s decreases the downwash and increases the outwash and the swath width

- Increased forward speed means swath width increases
- Into-wind and with-wind profiles show the same characteristics
- The increase in swath width with forward speed provides deposits between the two swaths and maintains biological effect

Forward speed affects spread; wind heading affects deposition pattern.

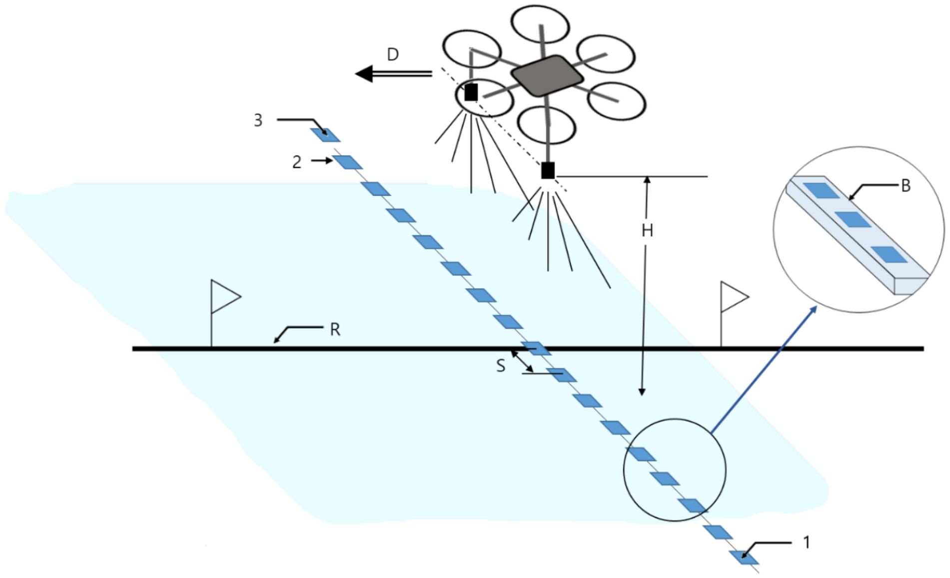

Ground Effect: The PV 22 doesnt have RTK GPS: Forward speed would have maintained so this is an artifcat of reduced altitude
250
200
150
100
50
0
Win Dir
-5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
Distance m

UASS swath testing ISO

Maximum distance between collectors is 0.5 m 10 cm or less above the ground

Nozzle/atomizer type, size, configuration and height the flight speed and position of flight line, wind speed and heading

For single spray pattern, the test spray deposition shall be expressed **in amount of spray liquid or tracer per unit area (e.g. µl/cm2, ng/cm2), % of spray volume applied,** % of coverage of a collector or number of droplets per unit area on different collector locations



Key

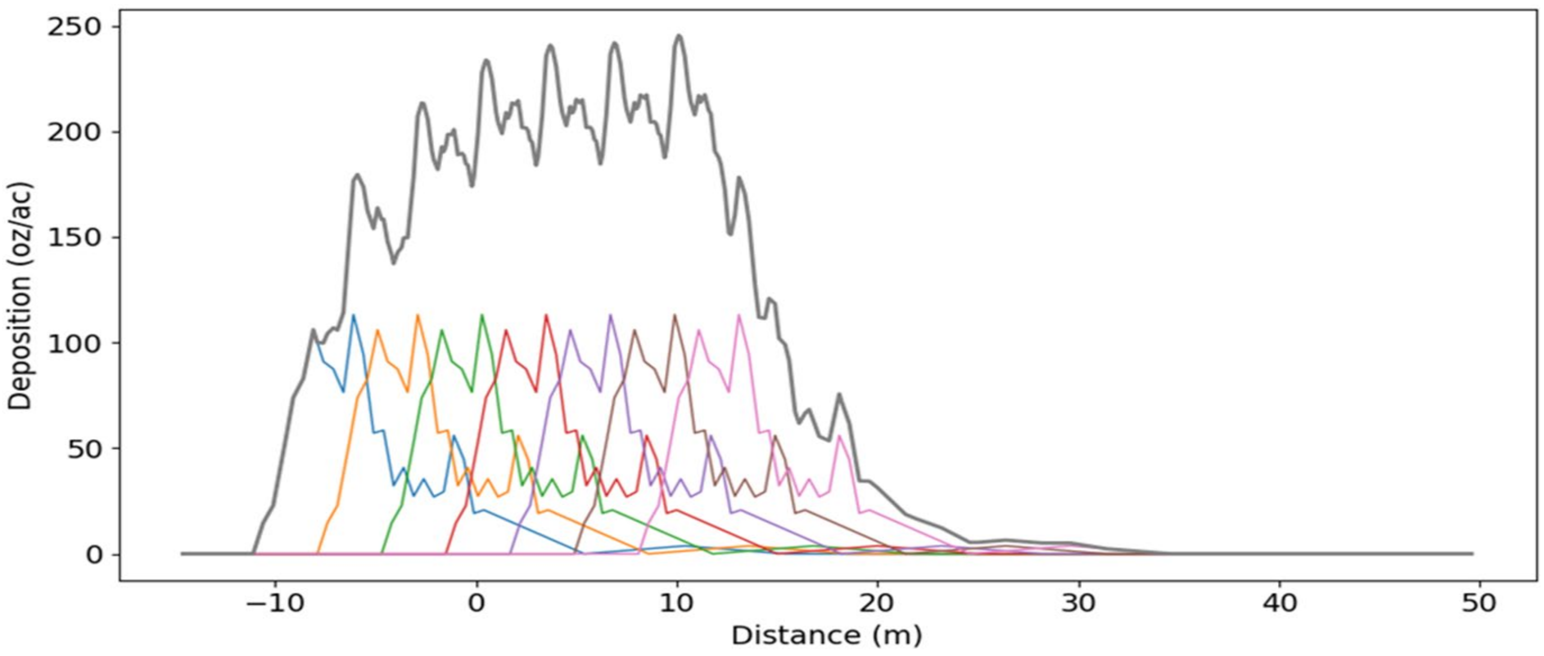
- B bar or plate
- D spray flying direction
- H nozzle height
- R flight route
- S collector spacing
- 1 left end (1st) collector
- 2 the (n-1)th collector
- 3 right end (n-th) collector

Example of the collectors' disposition

Swath Offsetting

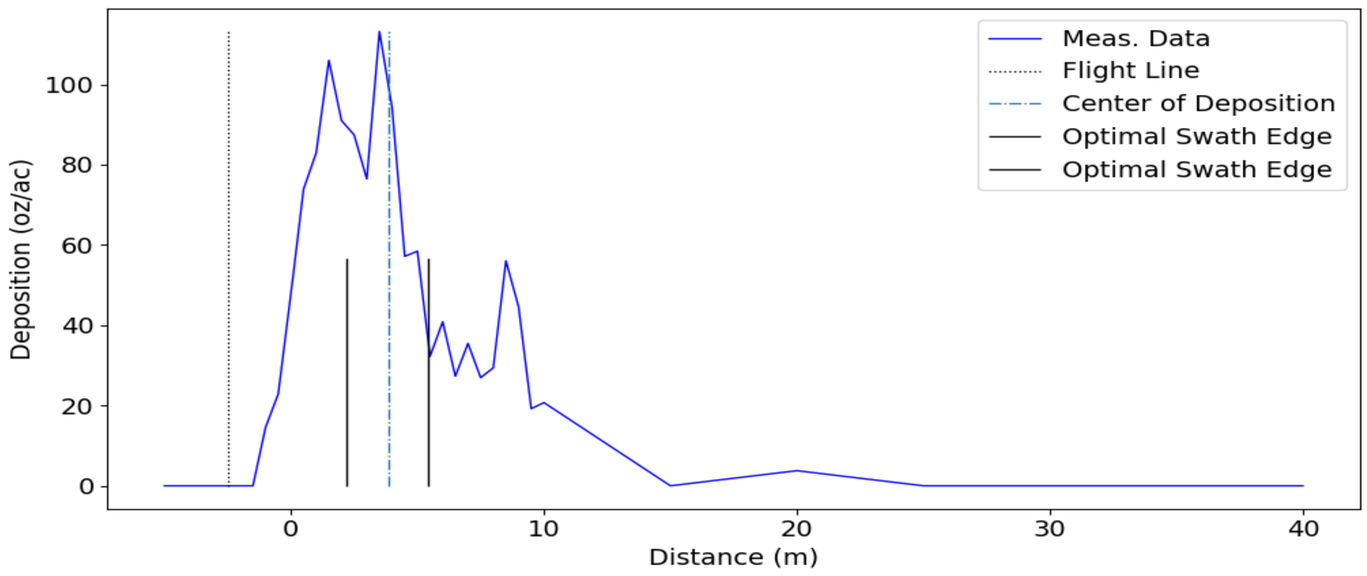
- It is important to understand the appropriate offset under any given condition to ensure that the application stays on target.
- Wind driven offsets for manned aircraft are typically <30% of the swath width.
- Manned aircraft applicators routinely offset half a boom width upwind at edge of field.
- For UASS the swath can be offset by more than 100% of the swath diameter. We need to provide operators with information that will help ensure that the spray volume remains in the target area.

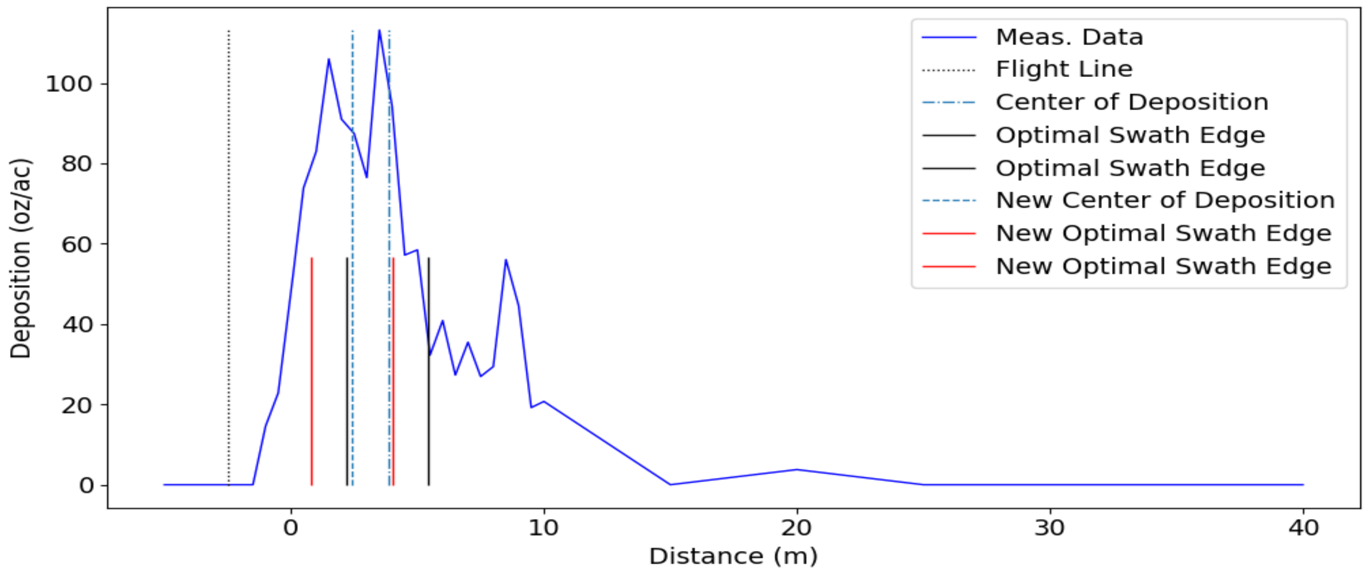
Swath	Rate	RT
1	484.00000	2.40000
2	319.60000	1.50000
3	224.60000	5.10000
4	169.50000	12.00000
5	138.10000	12.00000
6	115.90000	18.60000
7	99.30000	30.10000
8	86.60000	38.20000
9	77.10000	42.10000
10	69.40000	43.50000
11	62.90000	45.50000
12	57.60000	49.10000
13	53.20000	54.20000
14	49.40000	60.60000
15	46.10000	67.80000
16	43.20000	75.10000
17	40.70000	81.60000
18	38.40000	87.30000
19	36.40000	92.10000
20	34.60000	96.10000



The distribution pattern is stacked with theoretical swath widths of 1 – 20 m

For manned aircraft the CV must be lower than 20 % which would return half the required dose.
Our primary driver must be dose a field bioassay returned an LD90 of 212 oz/ac (15 L/ha)
The calculated effective swath to deliver the optimal dosage is 3.2 m with a corresponding CV of 8.4%.





The swath for this profile was determined to be 3.2m not 5m

This is a Center of deposition incorporates the whole drift profile shifting the swath significantly downwind, likely not conservative enough

Conservative Approach

Take the CoD (2.9 m) for the whole profile + 0.5 * the swath width 1.6 m makes downwind **Edge of Field 4.5 m**

Recalculate the CoD for these upwind measures returning a final CoD value is 2.1 m swath displacement of

2.1 – (-2.5)

The Edge of Field 3.7 m

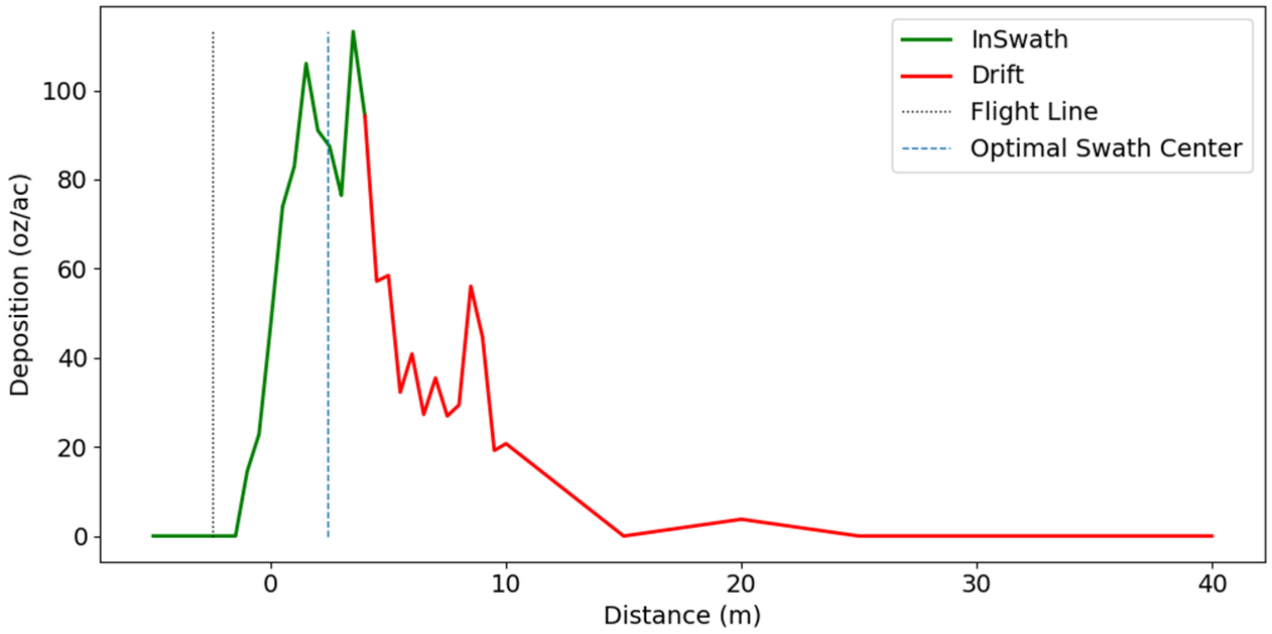
Targeting and swath offsetting

The swath for this profile was determined to be 3.2m not 5m

Then you calculate center of swath, we use CoD as it provides more appropriate determination of center for muti peaked non uniform spray patterns

Flightline is offset by 4.6 m, which is larger than the swath

With enough data this information can develop a knowledge base to incorporate wind driven offsets into our flight planning keeping the last swath in field.



Future focus

Researchers need to be mindful that there are too many unknowns with high variability to make any assumptions

UASS setting, manual checks are required along with full reporting.

The flow rates and speeds are controlled we need controlled measures of swath.

Guidance for measuring off-target movement from uncrewed aerial spray systems: methods to support regulatory spray drift assessment

Jane A. S. Bonds,*, Naresh Pai, Francis P. Donaldson, Michael Bird, Jason McDonald, and Monika Maleri

Questions

Jane Bonds jasbonds@gmail.com