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Experimental evaluation of a spray drift Gaussian tilting plume model

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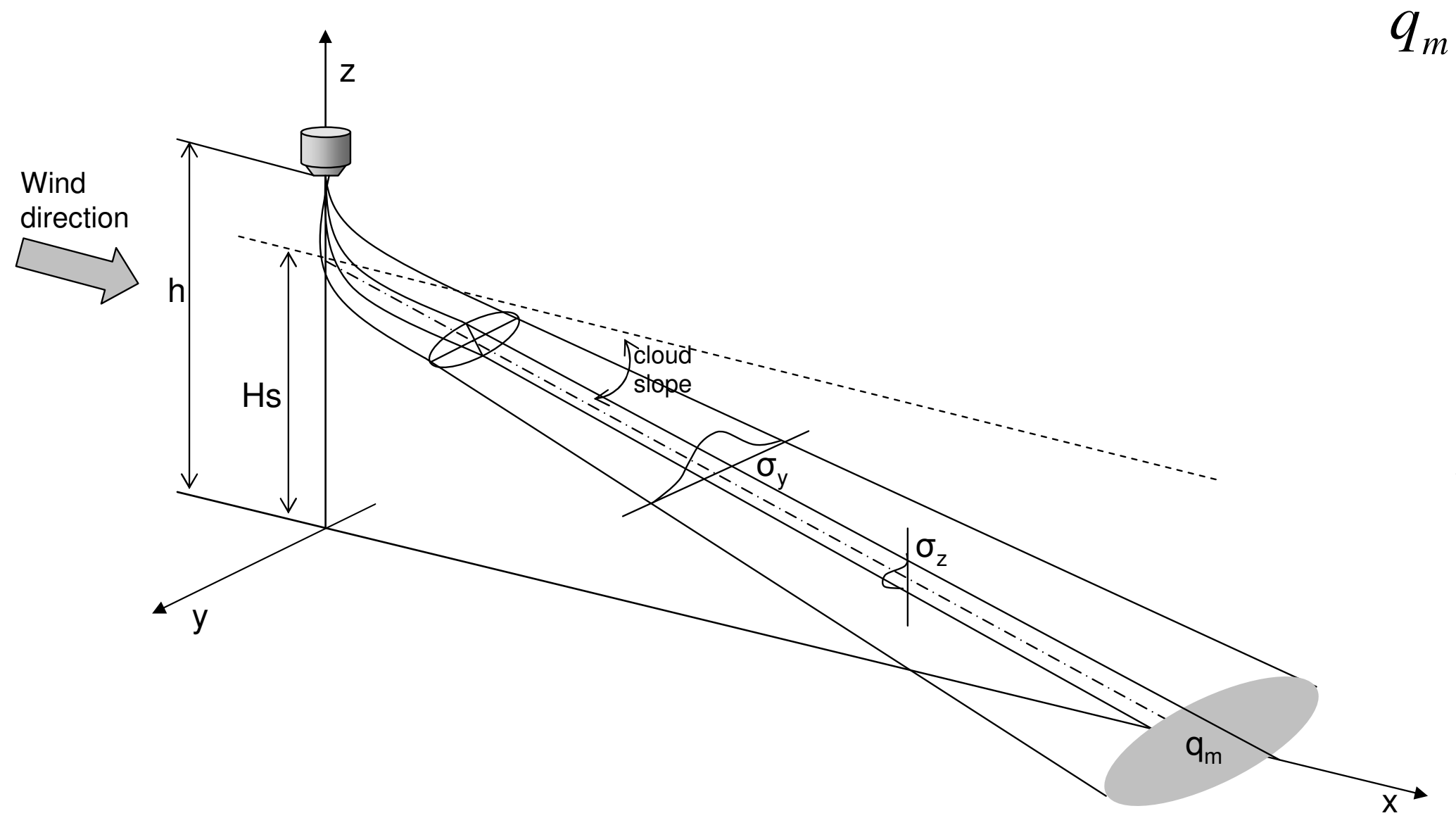
Fundamental equation

The objective of this research is to evaluate a Gaussian tilting plume model that takes into account the spray characteristics of agricultural nozzles to predict drift. The application of this type of model has proved to be effective for aerial pollution applications. To be applied successfully to the spray drift, the model has to give accurate predictions of the deposits regarding the spray and material characteristics as well as the weather parameters. To reach this objective, the model parameters must be correctly set based on appropriate theoretical basis and experimental data.

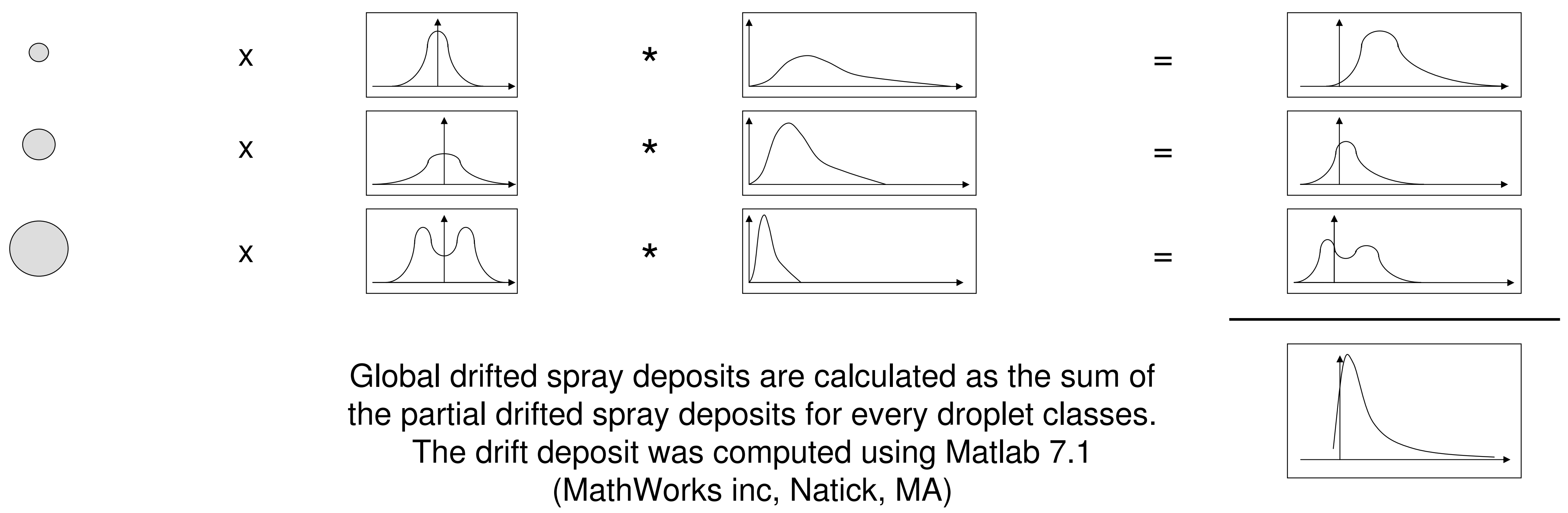
Spray drift footprint equation



$$q_m = v_p C(x,y,0;Hs) = \frac{Q_m v_p}{2\pi\sigma_y\sigma_z U}\exp\left[-\frac{y^2}{2\sigma_z^2}\right] - \left[\frac{\left\{\left(Hs-\frac{v_p x}{U}\right)\right\}^2}{2\sigma_z^2}\right]$$

q_m : particle deposit rate ml/(m²s).
v_p: sedimentation speed of particles (m/s).
C(x,y,z;Hs): deposits as a function of the position in the wind direction (ml/m³);
x: horizontal distance along the wind direction (m);
y: horizontal distance perpendicular to the wind direction (m);
z: height from the ground (m);
Hs: modified height of the particles emission point (discharge height) (m);
Qm: particle flow rate (ml/s);
σ_y: dispersion coefficient along y axis (m);
σ_z: dispersion coefficient along z axis (m);
U: mean wind speed along x axis (m/s);

Spray drift model



The spray droplet population may be divided into homogeneous size droplet class

Spray distribution under the moving boom for each droplet size class

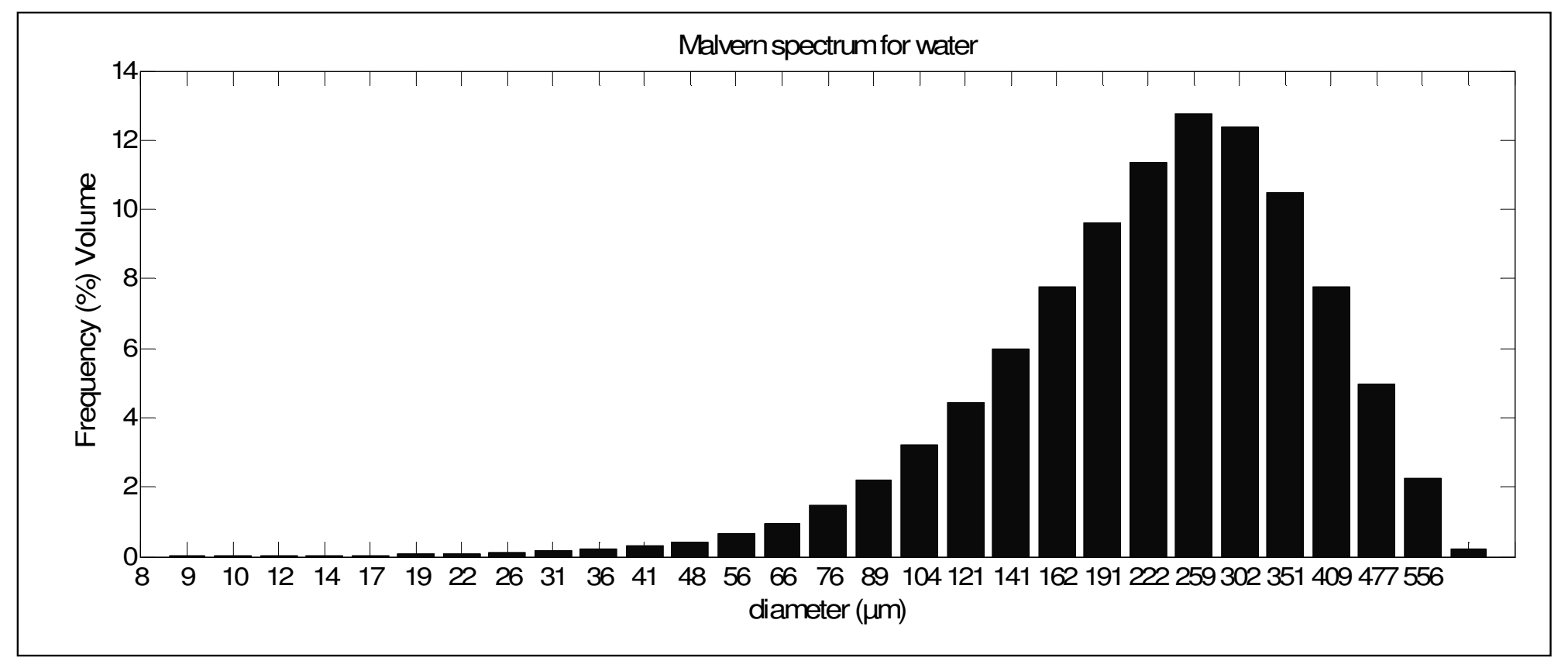
Footprints are computed modifying the size sensitive parameters for each droplet size class

Partial drift is computed as the result of a 2-D convolution of the product of the percentage of droplets by the spray distribution with the corresponding footprint for each droplet size class

Global drifted spray deposits are calculated as the sum of the partial drifted spray deposits for every droplet classes. The drift deposit was computed using Matlab 7.1 (MathWorks inc, Natick, MA)

Model parameters settings

Number of droplet classes:
The Malvern droplet sizer measurements shown are composed of 30 droplet classes of homogeneous size that are used as model input classes.



Footprint parameters

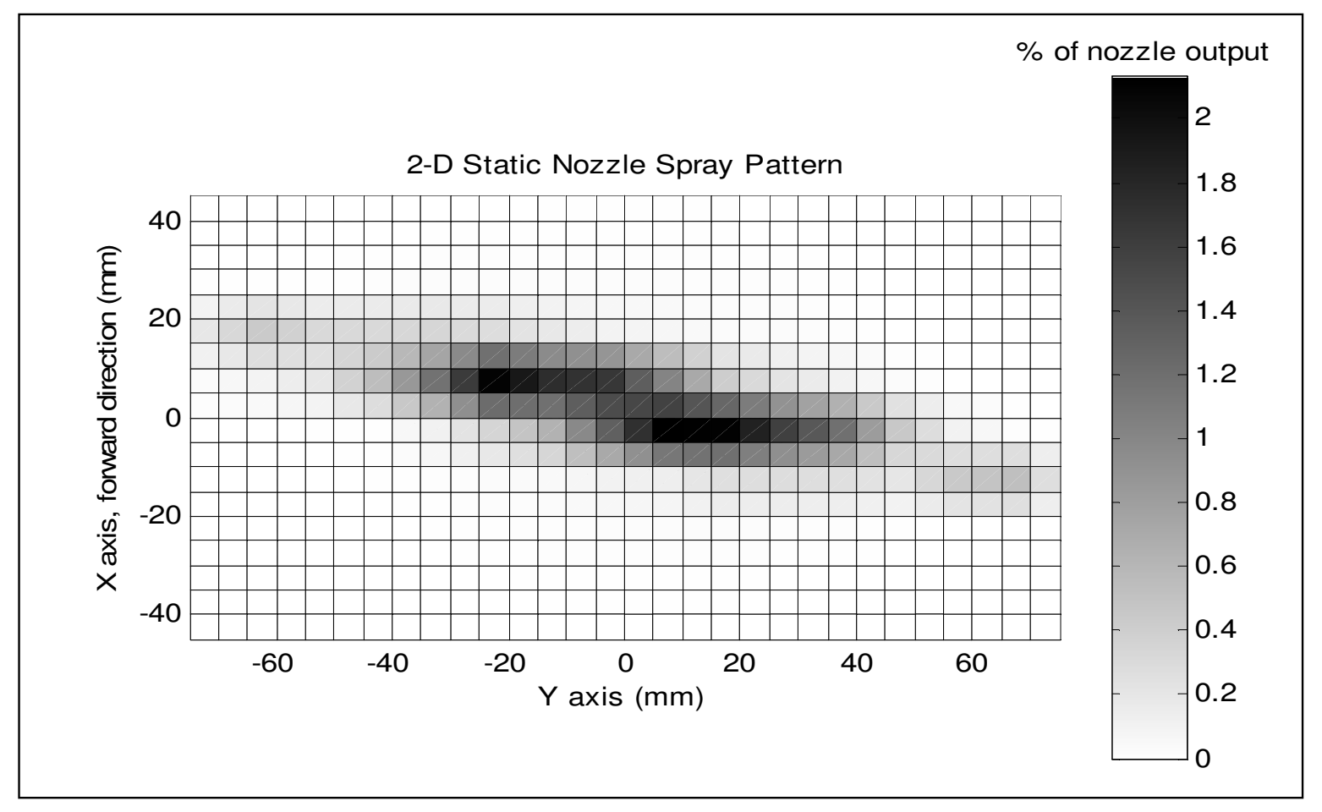
Sedimentation speed of particles (v_p) :
Evaluated using Strokes law

Particle flow rate (Q_m):
Nominal flow rate of tested FF120/0.8/3.0 nozzle with a 3 bar pressure

Dispersion coefficient along y and z axis (σ_y ,σ_z):
Set to 0.05 m corresponding to the turbulence intensity on bare ground in stable conditions.

Mean wind speed along x axis (U):
Mean wind speed was set equal to 2 m/s.

Nozzle spray pattern:
Figure 1 presents the result of the two-dimensional static spray pattern. The nozzle was mounted with the recommended angle used to avoid adjacent spray interference



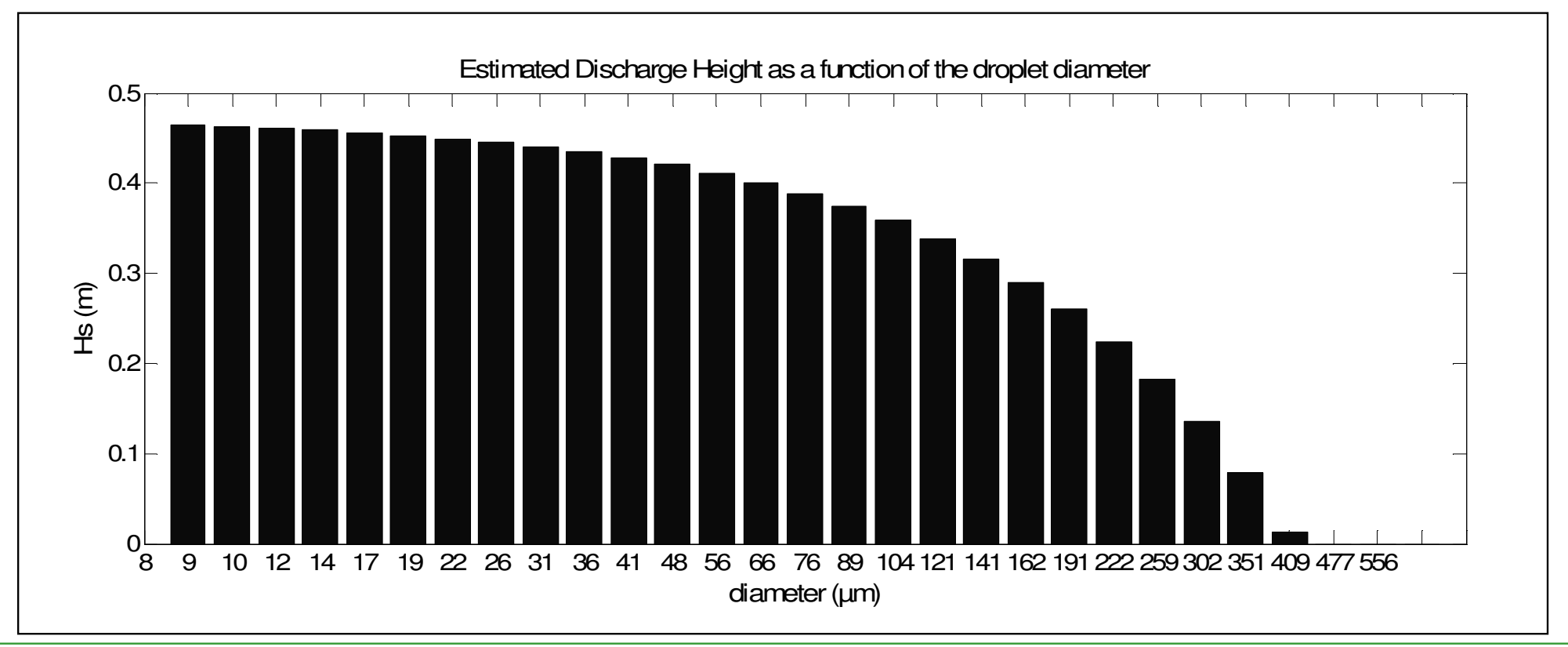
Modified discharge height (Hs):
The following equations were used to estimate the distance from the nozzle where the droplet velocity is reduced enough to become influenced by the lateral wind. The optimal value of *Vl* was estimated 5.6m/s fit for a 2m/s lateral wind. Afterwards, Hs, the height where each droplet class reaches the limit speed is computed as nozzle height less the corresponding *r* value.

$$V_l = V_{l0} e^{-\lambda(r-r_0)}$$

$$\lambda = \frac{3C_D\rho_a}{8a\rho_l}$$

Vl: droplet velocity at distance l (m/s)
Vl0: initial droplet velocity (m/s)
r: distance from the nozzle (m)
r0: length of the liquid sheet (m)

CD: drag coefficient
ρa: air density (kg/m³)
ρl : liquid density (kg/m³)
a: droplet radius (µm)

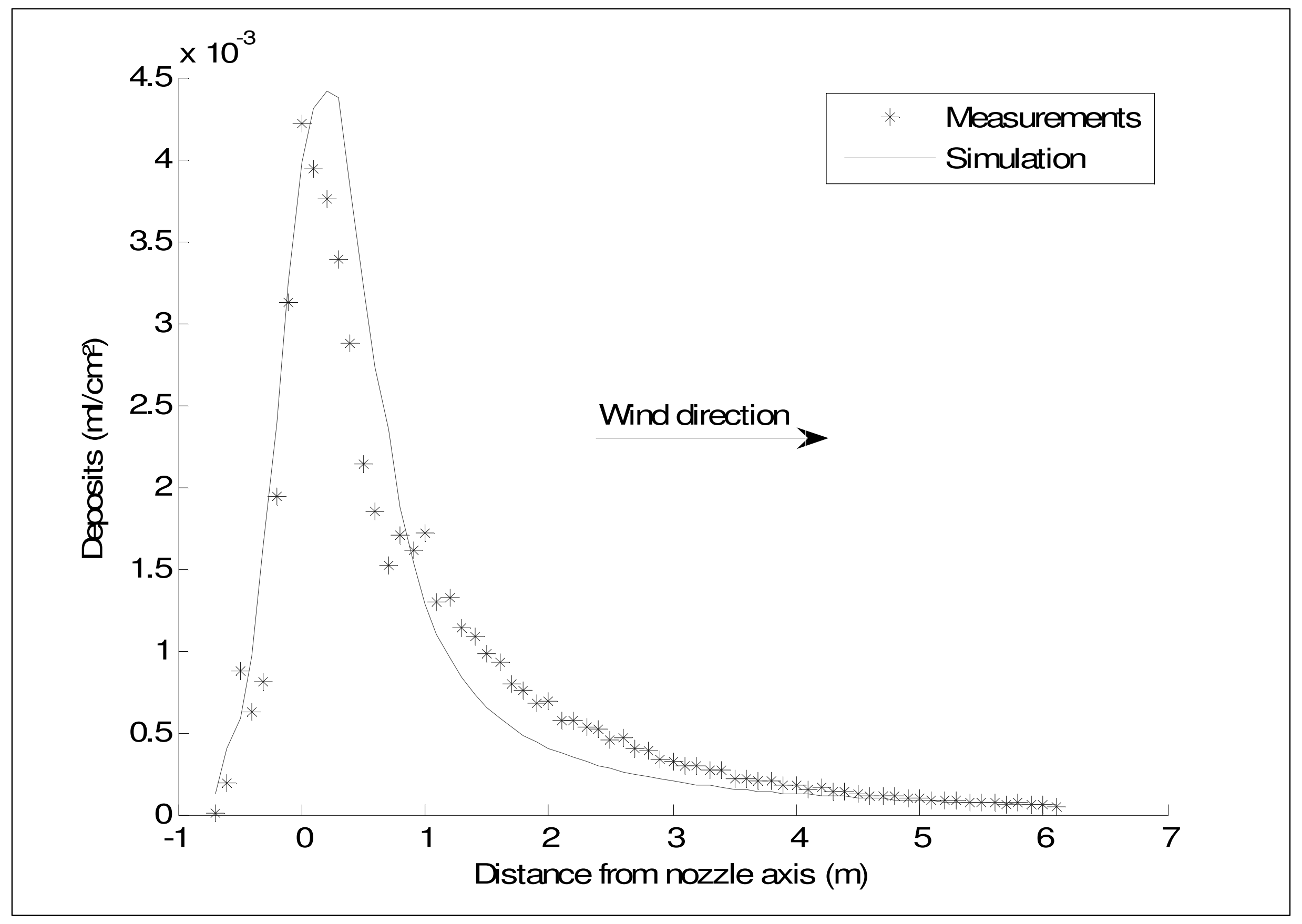


Results and discussion

Modelled drifted spray deposits presents good general agreement with the measured deposits. However in the spray pattern zone, from -0.7 to 1 m, the modelled nozzle spray pattern showed a bit too large diffusion and wind transport of the large droplets meaning that their sensitivity to drift is overestimated. It does explain that the irregularities observed in the bell-shaped curve of the measured deposits, related to the nozzle spray pattern, are smoothed by the model. This last effect can also be related to the simplistic and erroneous assumption of even distribution of the spray droplets diameters inside the spray.

In the drift zone, from 1 to 6 m, it is observed that the spray deposits are underestimated, what reflects that the effect of drift on small droplets is lowered. However, the drift further than 5.8 meters appears again overestimated. A better estimation of the footprint parameters is thus needed to further improve the model performance.

Modifying the diffusion coefficient regarding to the droplet size could be a way toward accuracy improvement as it is clear that bigger droplets are less prone to diffusion than smaller ones due to inertial effects. Furthermore, a better estimation of the modified discharged height, either on theoretical or experimental basis could also improve the prediction accuracy.



Conclusion

Based on literature resource and fluid dynamics equations, the effect of the most important characteristics of spray droplets from an agricultural nozzle has been modelled using a Gaussian tilting plume approach, discretizing the different droplet classes. Although the theoretical basis of the model is simple, the predicted drift appeared to be in relatively good agreement with the experimental results. The discrepancies could be explained by poor fitting of the different model parameters. Further work is required to optimise the value of the model parameters.