Challenges for CFD modeling of drift from air assisted orchard sprayers

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Introduction

Plant protection products (PPP) play an important role in providing high crop yields by minimizing risks associated with the occurrence of pests. Some of the sprayed material may however move beyond the intended target and results in drift to non-target objects. Modeling approaches help to understand, characterize and minimize spray drift using computer simulations rather than field experiments. However, modeling drift from orchard spraying presents particular challenges: (1) the moving spray interacts with the canopy before reaching the drift area and thus the airborne fraction of spray is reduced by tree interception (Duga et al., 2014); (2) the vertical wind profile changes from the orchard to the neighboring field that has a different vegetation (Duga et al., 2015); (3) the moving airjet from the air assistance cannot be ignored because the magnitude of the air jet velocity is typically higher than the wind velocity (Duga et al., 2015). As a result the modeling becomes rather complex. Here we present a CFD model of spray drift to calculate sedimenting and airborne drift from orchard sprayers in a typical apple orchard in Belgium that attempts to take these challenges into account. Preliminary results are shown that help to understand the spray drift modeling issues and are a basis for further model refinement and validation against orchard field drift measurements.

Materials and Methods

A CFD orchard drift model was developed based on a model for predicting the on-target spray distribution in orchards (Duga et al., 2015). The model considers the real architecture of the trees, the canopy wind flow and the moving sprayer outlet with dedicated spray nozzles. It then computes the tracks of representative droplets of the nozzle size distribution from the nozzle to the target, non-target surfaces directly around the tree and remaining in the air. This model was validated with on-tree measurements of deposition (Duga et al., 2015). The model considered trees within the bulk of the orchard and was restricted to a small domain around a single tree and two neighboring trees. For drift, however, a larger domain needs to be considered to predict the ground and airborne drift at larger distances behind a side row of trees. Ina first attempt, a computational domain having 12m height and 40 m length was used to represent the drift area next to the row of three orchard trees. The wind and the air flow from the sprayers were modeled using the Unsteady Reynolds Averaged Navier-Stokes (URANS) equations and the k-ϵ turbulence model which were solved using the unstructured finite volume method in a CFD code of ANSYS-CFX (ANSYS, Inc., Canonsburg, Pennsylvania, USA). The path of the spray droplets within the turbulent air flow field were tracked using the Lagrangian particle tracking multiphase flow model combined with acanopy deposition model(Duga et al., 2014).Architectural data of the trees was collected during field trials and used in the model simulations. We solved the model for a crossflow sprayer (DuoProp, BAB Bamps, Sint-Truiden, Belgium) in an apple orchard. The model can be easily adapted to other sprayer types and training systems (Duga et al., 2015). The calculations took a total CPU time of 144hours using two computing nodes on a KU Leuven HPC Linux cluster each having 64GB RAM.

Results

Fig.1 shows the predicted airflow, particle track and deposition contour plots of the one-sided spray application of the apple classical training system with the crossflow sprayer under a wind flow of 1.5 m/s (10 m height) and 85° angle to the spray direction. What is seen is the accumulated spray tracks emitted from 8 nozzles on the machine as the machine drives along the 3 trees. The combined effect of this wind and the spray jet results in a complex airflow through, around and beyond the tree that strongly affects the deflected spray. Within the canopy there is a considerable amount of deposition, but certainly a large amount of mainly smaller particles moves beyond the trees into the drift zone. Definitely, drift from orchard sprayers is a complex three-dimensional process that requires to include temporal dynamics (driving), tree interception, wind direction and magnitude, and machine and nozzle characteristics. However, we can also see the following limitations from this simulation result. First, the domain must be sufficiently wide to account for the deflected spray to deposit in the drift area such that accumulated drift curves with distance from the row can be established. Now, a significant part of the spray is still airborn when it leaves the CFD domain. Second, note that this simulation does only consider 3 trees in the row for computational reasons. As a result, air and spray are allowed to flow around the trees (avoiding their resistance). Thus, improved models must minimize this erroneous effect by modeling a longer row, which may not be computationally feasible, or implementing a simplified representation of the row. The CFD model will be adapted accordingly and validated against drift measurements from orchards.

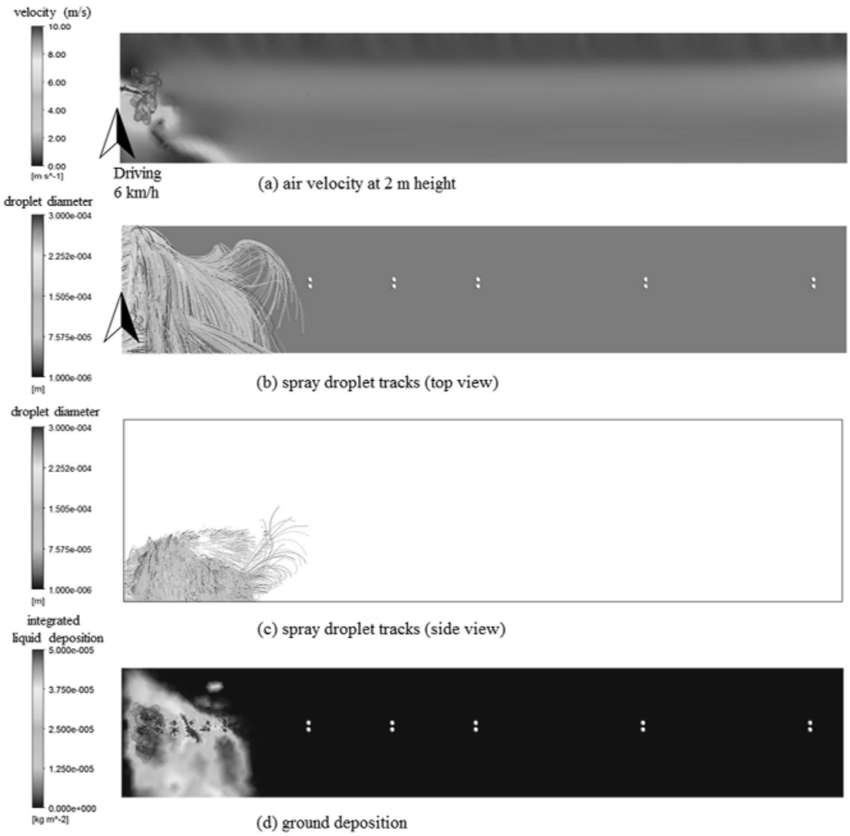

Fig. 1. CFD spray drift simulations

References

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