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A Windows Version of DRIFTSIM for Estimating Drift Distances of Droplets

Heping Zhu, Agricultural Engineer, USDA/ARS, Application Technology Research Unit, Wooster, OH, zhu.16@osu.edu

Robert D. Fox, Agricultural Engineer, USDA/ARS, ATRU, Wooster, OH, Columbus, OH.

H. Erdal Ozkan, Professor, FABE, The Ohio State University, Columbus, OH.

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Abstract. *Computer simulation provides a means of determining the relative effects of various factors on spray drift while field experiments to measure spray drift have the limitation that many variables cannot be controlled. A Windows Version computer program (DRIFTSIM) was developed to rapidly estimate the mean drift distances of water droplets discharged from atomizers on field sprayers. This program interpolates values from a large data base of drift distances originally calculated for single droplets with a flow simulation program (FLUENT). The simulations of drift distances up to 200 m (656 ft) included temperatures (10-30 °C; 50-86°F), discharge heights (0-2.0 m; 0-6.56 ft), initial downward droplet velocities (0-50 m/s; 0-164 ft/s), relative humidity (10-100%), wind velocities (0-10.0 m/s; 0-32.8 ft/s), droplet sizes (10-2000 μm), droplet size distribution in $D_{v,1}$, $D_{v,5}$ and $D_{v,9}$, and 20% turbulence intensity. Variables can be either in metric or English units. For the input of droplet size distribution, drift distances are reported along with portion of volume in each class such as provided by many droplet size analyzers. The accuracy of the program FLUENT was verified with a uniform droplet generator and wind tunnel. The program indicates the relative effects of the input variables on drift distances and should, especially for large droplets, provide reasonable accuracy for many field applications.*

Keywords. Computer program, Sprayer, Pesticides, Droplet size, Wind velocity, Nozzles

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Introduction

Spray drift, movement of pesticide droplets through air during or after application to a site other than the intended targets of application, is one of the most critical problems pesticide applicators have to deal with. For example, three-fourth of agriculture-related complaints investigated by the Ohio Department of Agriculture involved with drift issues; two-third of the total complaints in a five-year period brought to the attention of Iowa Department of Agriculture was related to drift problems; about one third of court cases due to spray misapplications reported by a major insurance company involved with drift damages. Drift problems will become even more critical in the future when farmers use more genetically modified crops which restrict use of non-selective herbicides because even a small amount of these herbicides can cause serious damages on neighboring crops.

Although complete elimination of spray drift is impossible, problems can be minimized if chemicals are applied with the proper equipment and methods under favorable weather conditions. Increased awareness of environmental quality and better understanding of the causes of spray drift can help operators make reasonable judgments for safer, more efficient applications.

Factors that significantly influence off-target movement of droplets are wind velocity and direction, droplet size and density, and distance from the atomizer to the target. Other factors that influence drift include droplet velocity, and direction of discharge from the atomizer, volatility of the spray fluid, relative humidity, ambient temperature, and atmospheric turbulence intensity. Many scientists have conducted field tests to study influence of these variables on spray drift. Unfortunately, field tests have the limitation that weather conditions cannot be controlled and the variables that influence spray drift may interact and vary during a test.

Computer simulations can allow determination of effects of different variables such as droplet size and velocity, relative humidity, and wind velocity on spray drift. One such a computer model or a commercially available computational fluid dynamics (CFD) program was evaluated by Reichard et al. (1992) in Ohio for modeling the effects of several variables on spray drift. Experiments were conducted to verify the accuracy of the computer model in predicting drift distances of water droplets in a wind tunnel with a single size droplet generator. These tests revealed that the computer model could be used to accurately calculate spray drift distances for a wide range of spray droplet sizes and wind velocities. With the computer model individual or mean droplet trajectories were determined for different values of several variables listed above (Zhu et al., 1994). However, the model is very expensive and requires special operator skills and a high-speed computer with a large memory space to operate. It also takes long time to calculate a drift distance even for a single simulation condition.

DRIFTSIM is a simplified and user-friendly version of a computer model developed with a visual BASIC language program to interpolate values from a large data base of drift distances originally calculated from the CFD model evaluated by Reichard et al. (1992). Detailed information on DRIFTSIM is given in a publication by Zhu et al. (1995). DRIFTSIM can be used to determine effects of major drift-causing factors on the mean drift distances up to 656 ft from the release point for individual water droplets or classes of droplets. These factors or variables used in DRIFTSIM are listed in Table 1, with the limiting values acceptable to DRIFTSIM.

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Variable	Range	
	American Unit	Metric Unit
Wind velocity	0-22 mph	0-10 m/s
Droplet size	10-2000 Micron (μm)	10-2000 μm
Droplet velocity	0-110 mph	0-50 m/s
Discharge height	0-6.5 ft	0-2.0 m
Temperature	50-86 °F	10-30 °C
Relative humidity	10-100 %	10-100 %

Turbulence intensity is another important factor indicating how much the wind velocity varies about the mean. It can vary considerably in field conditions, but based on the frequency of nearly 20% turbulence intensity observed in many of the field measurements conducted in Ohio, a constant value of 20% turbulence intensity was used in DRIFTSIM for all calculations.

For classes of droplets in this version of DRIFTSIM, the upper-limit log normal (ULLN) method (Goering and Smith, 1978) was used to calculate the drop-size distribution produced by a nozzle. The ULLN method used three size measurements, $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ to estimate the volume of spray in droplets less than a selected droplet size. The $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ for the droplet size spectra produced by a specific nozzle can be measured with most modern droplet sizing instruments. DRIFTSIM computes the drift distance for the average of lower and upper droplet size for each size class. It also computes the portion of spray in each size class.

Terms used in DRIFTSIM program

Single size droplets: For the program to calculate a mean drift distance of a given size droplets with other variables

Array of droplets (DVs): For the program to calculate drift distances with the portion of volume for many size classes of droplets by entering $D_{v,1}$, $D_{v,5}$ and $D_{v,9}$

$D_{v,1}$: Droplet diameter such that 10% of total liquid volume that is in droplets smaller than $D_{v,1}$ (micron or μm)

$D_{v,5}$: Droplet diameter such that 50% of total liquid volume that is in droplets smaller than $D_{v,5}$ (micron or μm)

$D_{v,9}$: Droplet diameter such that 90% of total liquid volume that is in droplets smaller than $D_{v,9}$ (micron or μm)

Array of droplets (nozzle): For the program to calculate drift distances with the portion of volume for many size classes of droplets by selecting nozzle type [*Note: In DRIFTSIM, data is available for only a limited number of nozzles*]

Temperature: Ambient air temperature during spray operation (°F in American unit or °C in Metric unit)

Relative humidity: Relative humidity of ambient air (%)

Wind velocity: Wind speed at nozzle level during the spray application (mph in American unit or m/s in Metric unit)

Discharge height: Nozzle orifice height above the ground (ft in American unit or m in Metric unit)

Droplet velocity: Velocity of droplets near the outlet of the nozzle orifice (mph in American unit or m/s in Metric unit)

Droplet diameter: Droplet diameter near the outlet of the nozzle orifice (micron or μm)

Operating pressure: Liquid pressure acting on the nozzle orifice (psi or kPa)

Operating DRIFTSIM

To operate DRIFTSIM, minimum requirements for a computer are Pentium PC with a CD drive, MS-Windows version 3.1 or later, 8 MB of memory, 30 MB free hard drive space, and a mouse.

DRIFTSIM is compact enough to fit on a CD. It can be operated from either a CD or a computer hard drive. DRIFTSIM automatically starts running when the CD containing DRIFTSIM is inserted in the CD drive of the computer. To operate the program from the computer hard drive, DRIFTSIM files and program should be first copied unto the hard drive, and then the user should execute DRIFTSIM.exe file to start the program. The program may run somewhat faster from a hard drive than a CD.

After the program starts, it gives three on-screen boxes for choosing units and droplet size types and entering values of simulation variables. A selection of units or droplet size types can be changed at anytime during the operation without necessary to exit the program. To change the value of any variable, simply click on the input area next to the variable, and enter a value that is within the acceptable range defined in Table 1. Only two screens appear during whole calculation process: input and result screens.

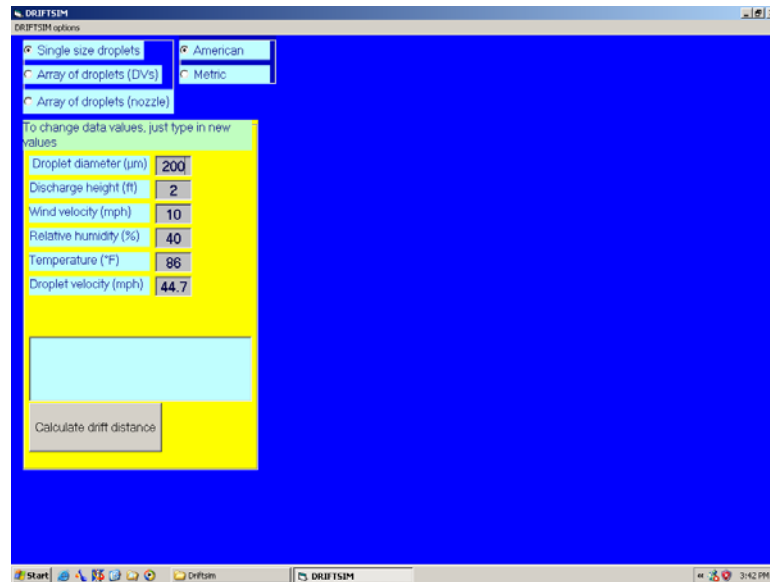
Steps to run DRIFTSIM from a CD

- (1) Insert CD in the computer.
- (2) Introductory information for DRIFTSIM as shown below appears on the screen.



- (3) Click on the “Start Driftsim” box. Three on-screen boxes for choosing and entering simulation conditions appear on the screen as shown below. [Note: initial values for drift

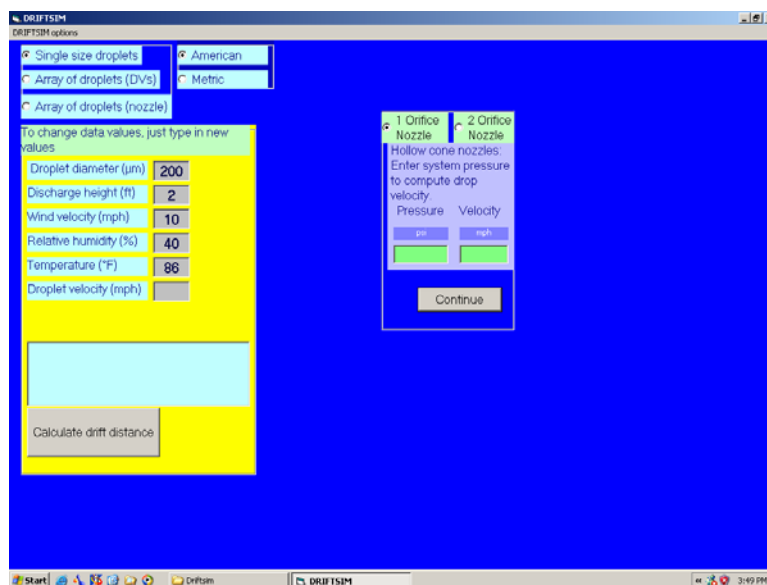
variables shown on the screen are built into DRIFTSIM. These values are only samples, not recommended values.]



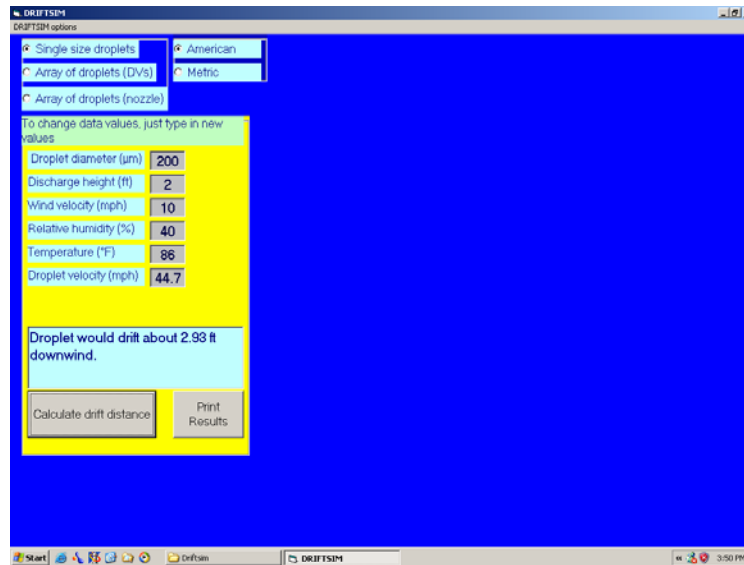
- (4) Select either “American” or “Metric” unit for calculation.
- (5) Select one of the three choices as a type of input for the droplet size: “Single size droplets”, “Array of droplets (DVs)”, or “Array of droplets (nozzle)”.
- (6) For “Single size droplets”, follow steps (7) to (12); for “Array of droplets (DVs)”, follow steps (13) to (18); for “Array of droplets (nozzle)”, follow steps (19) to (24).

[Steps (7) to (12) are for “Single size droplets” only]

- (7) Enter or change values for “Droplet diameter”, “Wind velocity”, “Discharge height”, “Droplet velocity”, “Temperature”, “Relative humidity” for inputs of variables. The value of “Droplet velocity” can be entered either by the user, or automatically by the program once the user enters a value for the operating pressure on the box which pops up on the screen as shown below after the user empties the “Droplet velocity” box. A red error message appears under the variable box if the value of an individual variable is outside the range defined in Table 1.



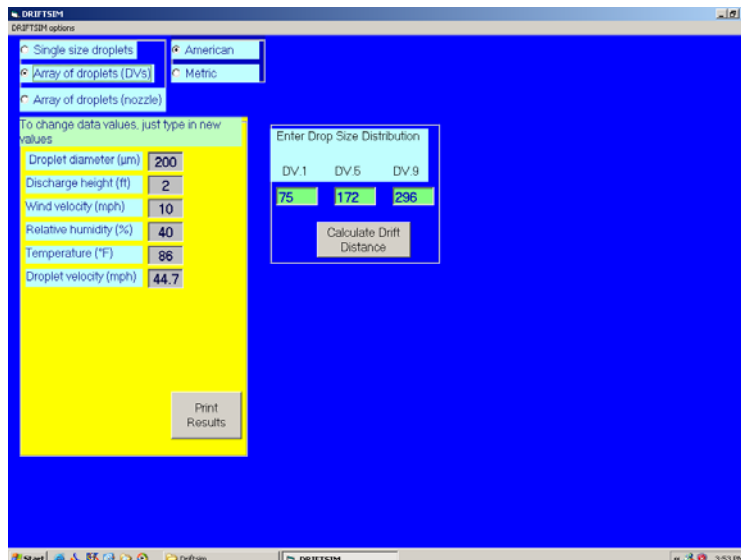
- (8) Click on “*Compute drift distance*” to obtain the results on the screen as shown below.



- (9) Click on “*Print results*” if you want to get a printout of input variables and the result.
 (10) To continue running DRIFTSIM with a new or revised set of inputs for the “*single size droplet*”, repeat steps (7) to (10).
 (11) If done with all the simulations, exit DRIFTSIM by clicking on the **X** at the upper right corner of the window on the screen if finished with all the calculations.

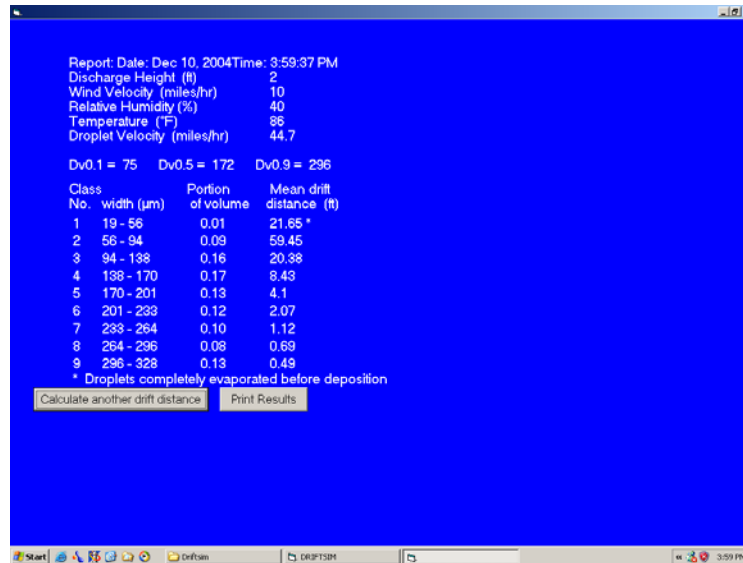
[Steps (12) to (18) are for “*Array of droplets (DVs)*” only]

- (12) After choosing “*Array of droplets (DVs)*”, a new box for droplet size distribution appears on the screen as shown below.



- (13) Enter “ $D_{v.1}$ ”, “ $D_{v.5}$ ” and “ $D_{v.9}$ ” values in boxes.
 (14) Enter or change values for “*Wind velocity*”, “*Discharge height*”, “*Droplet velocity*”, “*Temperature*” and “*Relative humidity*”.

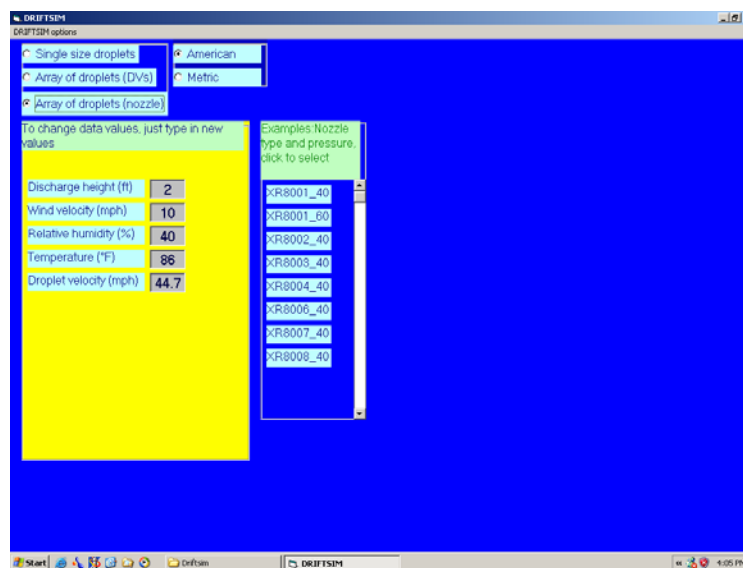
- (15) Click on “Calculate Drift Distance”. Drift distances of 9 size classes of droplets along with the portion of the spray volume corresponding to each size class appear on the screen as shown below. Error message appears on this screen if “ $D_{v,1}$ ”, “ $D_{v,5}$ ” and “ $D_{v,9}$ ” values are not reasonable.



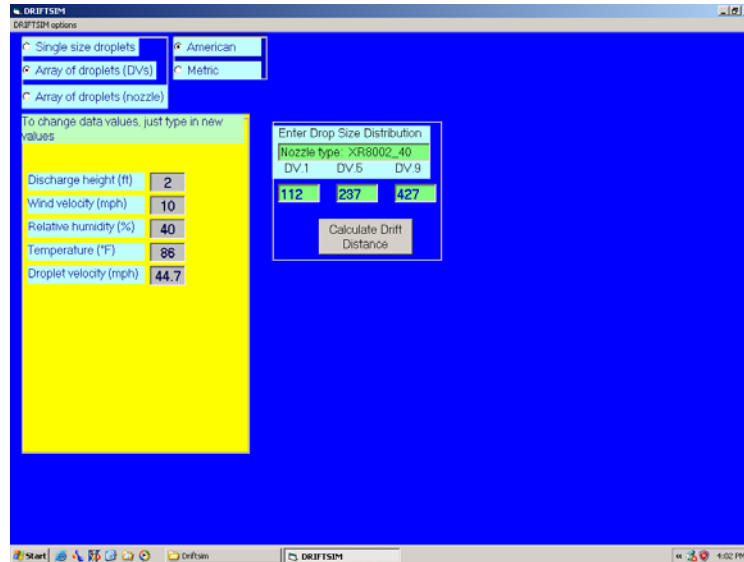
- (16) Click on either “Print Results” to get a printout of the results, or “Calculate another drift distance” to repeat steps (13) to (16) for a revised or new set of inputs.
- (17) If done with all the simulations, exit DRIFTSIM by clicking on the **X** at the upper right corner of the window on the screen if finished all the calculations.

[Steps (18) to (24) are for “Array of droplets (nozzle)” only]

- (18) After choosing “Array of droplets (nozzle)”, a new box with a list of several nozzles appears on the screen as shown below.



- (19) Click on one of nozzle choices, then “ $D_{v,1}$ ”, “ $D_{v,5}$ ” and “ $D_{v,9}$ ” values automatically appear in boxes for the nozzle chosen, as shown below.



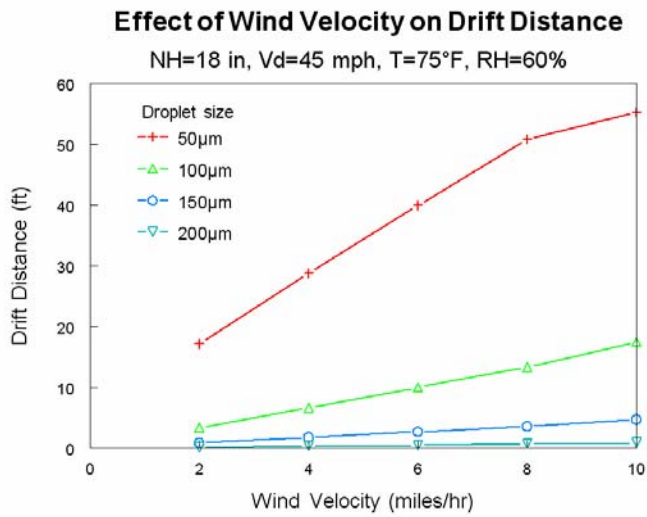
- (20) Enter or change values for “Wind velocity”, “Discharge height”, “Droplet velocity”, “Temperature”, and “Relative humidity”.
- (21) Click on “Calculate Drift Distance”. Drift distances of 9 size classes of droplets along with the portion of the spray volume corresponding to each size class appear on the screen as shown below. Error message appears on this screen if “D_{v.1}”, “D_{v.5}” and “D_{v.9}” values are not reasonable.
- (22) Click on either “Print Results” to get a printout of the results, or “Calculate another drift distance” to repeat steps (18) to (22) for a revised or new set of inputs.
- (23) If done with all the simulations, exit DRIFTSIM by clicking on the **X** at the upper right corner of the window on the screen if finished all the calculations.

Steps to run DRIFTSIM from a computer hard drive

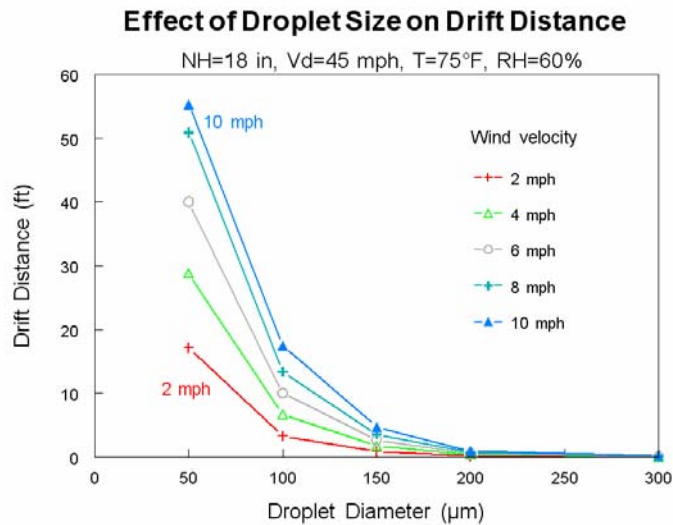
To operate DRIFTSIM from a hard drive, the user should copy both DRIFTSIM subdirectory and all contents in the subdirectory, except for AUTORUN.INF and Browsercall.exe, from the CD to the hard drive [*note: the subdirectory name must be DRIFTSIM; otherwise, the program will not work*]. Steps of copying files from the CD to the hard drive are: 1) click on **My Computer**, 2) click the **CD drive**, 3) on **File** menu, click **Open**, 4) click **DriftSim** subdirectory, 5) on **Edit** menu, click **Copy**, 6) click **Back**, 7) double click **Local Disk (C:)**, 8) on **Edit** menu, click **Past**, then all files and subdirectory **DriftSim** are copied to the hard drive. After the copy is completed, go to **DriftSim** subdirectory in the hard drive and click on **DriftSim.exe** file. DRIFTSIM introductory page should appear on the screen. Then follow steps (3) to (23) above to run the program.

Examples of drift estimation from DRIFTSIM

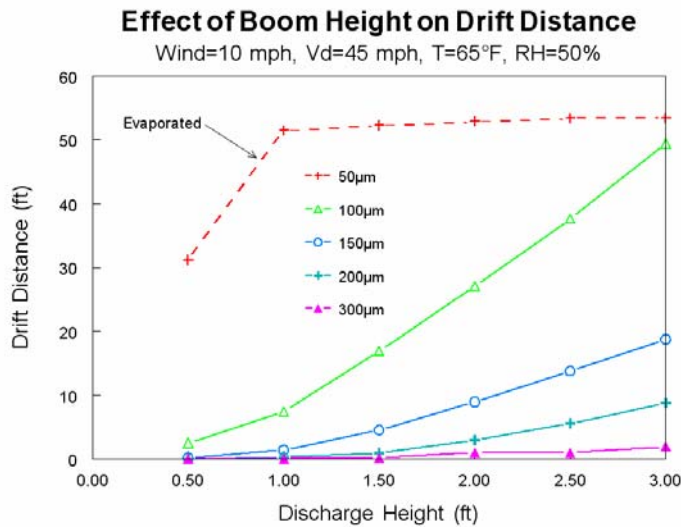
(1) Effect of wind velocity on drift distances for droplet size ranging from 50 to 200 μm at nozzle height of 18 inch, initial droplet downward velocity of 45 mph, ambient temperature of 75°F and relative humidity of 60%.



(2) Effect of droplet size on drift distances for wind velocity ranging from 2 to 10 mph at nozzle height of 18 inch, initial droplet downward velocity of 45 mph, ambient temperature of 75°F and relative humidity of 60%.



(3) Effect of nozzle height on drift distances for droplet size ranging from 50 to 300 μm at wind velocity of 10 mph, initial droplet downward velocity of 45 mph, ambient temperature of 65°F and relative humidity of 50%.



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