

**DEPOSITION MODELING
FOR
RISK ASSESSMENT
AND
DECISION SUPPORT**

**October 29, 2005
Waikoloa, Hawaii**

Organized by
Harold Thistle, U.S. Forest Service

Modeling Workshop Abstracts

Overview: Deposition Modeling for Risk Assessment and Decision Support

Harold Thistle
USDA Forest Service

There is substantial interest in the field of applied deposition modeling to predict the position a sprayed or spread pesticide will land. Modeling is pursued because it allows multiple scenarios to be run relatively quickly and at low cost. Though modeling will never replace data collection, its use as an analytical tool in training, planning, regulation and post-spray analysis is apparent. However, various types of models are utilized and it is critical for the user community to be familiar with the available tools and to be able to recognize the limitations of the various modeling approaches.

Deposition modeling of pesticide sprays presents a substantial challenge in detail. The position of deposition of a sprayed material is critically dependent on the drop size distribution of the released material but atomization remains a very difficult problem to model generically. Most of the models therefore depend on look-up tables, user input, or based on more recent work, statistical calculators for drop size input. Beyond the nozzle, the releasing vehicle may have an important effect on the position of droplets. Finally, transport through the atmosphere beyond the effects of the release mechanism and machinery must be addressed.

Generally, the types of models that are encountered are 1) full physics models that attempt to utilize a Navier-Stokes form of the scalar transport equation 2) hybridized physical models that explicitly handle parts of the physics but parameterize other parts 3) Gaussian models that make a priori assumptions about the shape of a plume and the distribution of material within a plume and 4) purely statistical models. Most applied deposition models utilize components from some or all of these model categories.

The objective of this workshop is to expose the user community to the nature and limitations of the various modeling approaches encountered in pesticide deposition modeling. The focus is on widely used techniques but other techniques are presented for perspective. It is believed that a better understanding of these models will allow the users to more effectively utilize models as analytical tools as well as understand the errors and implications of the model method as the modeled result is taken forward into exposure and risk modeling.

AgDRIFT / AGDISP Model Capabilities

Milton E. Teske
Continuum Dynamics, Inc.

This presentation will review the model capabilities present in both the USDA Forest Service (FS) aerial application development model AGDISP and in its Spray Drift Task Force (SDTF) regulatory version AgDRIFT.

Drift of pesticides from the target site during aerial spray applications is a source of environmental concern due to its potential human health impacts, downwind contamination and damage to crops and livestock, and endangerment of ecological resources. The sensitivity of drift to numerous factors, including atmospheric conditions and application equipment, makes field testing the full range of possible meteorological and application scenarios difficult. Modeling provides a coherent framework for evaluating the potential risks of spray operations and the potential effectiveness of possible mitigation options.

Modeling Workshop Abstracts

Over the last 25 years a significant modeling and data collection effort has been undertaken by the FS and its cooperators to develop accurate, validated models that predict the behavior of pesticides applied by aerial application above forests. After a significant effort directed toward the development of the Gaussian slanted plume model FSCBG, the focus shifted to the Lagrangian trajectory model found in AGDISP. The reason was simple: incorporating the local effects of the aircraft wake (the aircraft vortices) was essential to recovering an accurate, physics-based simulation of the behavior of material released from spray booms. In the mid-to-late 1990s this effort was supplemented by the SDTF, in response to re-registration of its agricultural pesticide products with the U. S. Environmental Protection Agency. A regulatory version of the Lagrangian model, identified as AgDRIFT, resulted. An extensive field study and model validation effort confirmed the predictive capability of the Lagrangian computational engine that drives the near-wake solution scheme in both AGDISP and AgDRIFT.

The real power of these models lie in their relative simplicity. AGDISP and AgDRIFT do not employ a “full-physics” Navier-Stokes approach, but instead incorporate a much simpler method that yields high correlation with observed deposition, and comes with rapid calculation times. The ideal model for evaluating off-site movement of pesticides, setting buffer zones around sensitive areas, and determining effectiveness of mitigation options needs to include mechanistic descriptions of important processes such as gravitational acceleration, air resistance, droplet evaporation, and mode of application. The Lagrangian approach formulated in AGDISP and AgDRIFT lends itself to this detailed modeling and thus, as an approach, most effectively meets the needs for a regulatory assessment tool that can be used to evaluate the mitigating effects of alternative equipment uses and near-field buffer zones.

Both models are based on a Lagrangian approach to the solution of the spray material equations of motion, and include simplified models for the effects of the aircraft wake and aircraft-generated and ambient turbulence. Vortical swirling behavior is quantified by a simple model that, when combined with the local wind speed and with gravity, effectively predicts the motion of released spray material. The original AGDISP model included the innovative step of developing ensemble-averaged turbulence equations to predict the growth of the spray cloud during the calculations, eliminating the need for a random component in the solution procedure.

In spray drift modeling the initial focus and original applications of the AGDISP model were primarily toward defining in-swath deposition patterns or as a near-wake model for forestry or other high-release applications where calculations for downwind deposition were made following a handoff from the Lagrangian calculations to a Gaussian plume algorithm. More recently, the use of AgDRIFT as a tool for assessing off-field drift and mitigation of drift from low-flight applications for regulatory decision-making extended the Lagrangian model accuracy to approximately 800 m downwind, and opened the door for improved solution handoff to developing mesoscale atmospheric transport models and generalization of the solution approach to three-dimensional simulations.

To make an accurate prediction of deposition and downwind drift, the model requires a consistent set of inputs representing the aircraft and its flight condition, the nozzles and the drop size distributions they create, spray material properties, surface features, and ambient meteorology. These inputs drive the various elements of the model used to approximate the physics within the wake behind the spray aircraft and into the local environment. In their current configuration the models include the following features:

1. A Tier structure consistent with level of input detail, and including Tier 1 ground and orchard airblast models (AgDRIFT only);
2. Extensive libraries of aircraft, drop size distributions, and canopy structure, in addition to multiple regression models for the generation of drop size distributions for hydraulic nozzles and rotary atomizers;

Modeling Workshop Abstracts

3. Atmospheric stability effects and the behavior of vortical decay in and out of ground effect;
4. Model inputs grouped within several broad areas of classification, relating to a description of the aircraft and its power plant (rotor or propeller), the nozzles on the spray boom and the drop size distribution they create, spray material details, ambient meteorology, surface features, and other needed field information; and
5. Extensive toolbox features, available to assess the consequences of the predicted scenario, including deposition, stream, and multiple application assessments.

AgDRIFT and AGDISP model capabilities will be highlighted in this talk, and an afternoon hands-on session will permit users to run scenarios of interest to them. Model development is ongoing, as the models expand to a wider user base, focused most recently on vector control scenarios and Spray Advisor.

Recent Additions to the AGDISP Aerial Dispersion Modeling System

Harold Thistle
USDA Forest Service

The AGDISP Spray Deposition Model is presented in detail in other sessions of this workshop. This talk is to specifically address new modeling capabilities that have been added to AGDISP. This talk discusses four additions:

- 1) A Canopy Library so that canopy architecture can be input from a look-up table. The look-up table now contains over 80 entries, with an indication of the origin of the LAI profile. The library also includes a generic composite deciduous profile and a generic composite coniferous profile for use when more detailed information is not available.
- 2) Atmospheric Stability is now input to AGDISP in a discrete scheme. Stability is used to modify the aircraft wake vortices, adjust the wind profile and alter turbulence parameters.
- 3) A Rotary Atomizer Drop Size Distribution Calculator is being added to AGDISP. This will allow the user to input flow rate, blade angle and aircraft speed (to obtain RPM) and will output DSD for a given material. This model is statistically based and is only valid for the specific materials tested in the ranges tested.
- 4) A Gaussian Extension has been added to AGDISP to extend the predictive capability of AGDISP to distances greater than 1000 m. If this option is chosen by the user, AGDISP calculates the distance at which the aircraft vortices are gone and only fine droplets are left airborne, these droplets are then handed off to a standard Gaussian dispersion model.

Atomization Models

Andrew J. Hewitt
Centre for Pesticide Application and Safety

Droplet size is often considered to be the most important variable in spray application for control of pests, weeds and diseases, and delivery of fertilizers and other agricultural products (Hewitt, 1997). Extensive research around the world over the last few decades has shown that the main control over droplet size can

Modeling Workshop Abstracts

be achieved through selection of the best nozzle or atomizer, and its setup and use on the sprayer (liquid/air pressure, angle, sprayer speed, etc). The tank mix can also have an important effect on droplet size, through determining the liquid physical properties of surface tension, shear and extensional viscosity. The provision of an accurate droplet size spectrum is essential for modeling, label compliance and other issues relating to pesticide application. Droplet size information can be obtained from several sources. These include nozzle catalogs, which typically do not provide sufficient information because they usually relate only to applications of *water* under *ground* spraying conditions. Actual wind tunnel measurements of droplet size under the application conditions and for the tank mixes of interest in a specific modeling exercise provide the most useful and accurate source of droplet size input. Most models assume a specific format for such data, and an appropriate measurement technique and dynamic size range. Another excellent source of droplet size “data” for modeling comes from established atomization models. Several models have been developed based on wind tunnel measurements from different sources. These will be discussed in this presentation. The main ones are as follows:

- USDA-ARS atomization models for aerial application of water-based sprays (water+surfactant), using PMS measurements in an open-fan wind tunnel. The latest USDA models can be downloaded from <http://apmru.usda.gov> Downloads
- SDTF atomization model for a wide range of tank mixes and nozzles tested in SDTF studies with laser diffraction measurement techniques, DropKick® (e.g. Hermansky, 1998) - however, since a single approach was used to solve data from a wide range of nozzle and tank mix types, the output of DropKick may not cover some conditions as accurately as others
- Specific models from sources such as the University of Queensland, SERG, etc – often covering atomizer types not covered elsewhere, such as rotary atomizers, with water-based and ULV or oil based products. Some models have been developed to allow real-time use in controlling droplet size while spraying, e.g. the JARBA model for controlling nozzle angle during aerial application - <http://www.jonesair.com.au/Nozzlecalc>

Where a model does not cover the exact tank mix and nozzle/ application conditions for a given scenario requirement, the closest available data set should only be considered to provide an *estimate* of the likely droplet size classification and spectrum for that assessment. Actual data for the specific conditions, especially if using adjuvants in the spray, may differ from the model output. It is also important to consider droplet size data from several different sources such as wind tunnel data, atomization models and, where available, field measurements. Such data should be carefully considered in context of sampling approaches, dynamic resolution ranges and relevance to the intended use.

Hermansky, C. G. (1998) A Regression Model for Estimating Spray Quality from Nozzle, Application, and Physical Property Data. *Proc. ILASS Americas 11th Annual Conference: Sacramento CA.*

Hewitt, A. J. (1997) The Importance of Droplet Size in Agricultural Spraying. *Atomization & Sprays* Vol. 7 (3), pp. 235-244.

AgDRIFT for Ground and Orchard Applications

Andrew J. Hewitt

Centre for Pesticide Application and Safety

The AgDRIFT model (Teske *et al*, 2002) includes modeling of aerial, ground and orchard spray applications. While the aerial model includes full access to all variables affecting spray transport and deposition, the ground and orchard models include options for more restricted use ranges. An example of

Modeling Workshop Abstracts

the screens with default input settings for the ground and orchard models at Tier I of AgDRIFT version 2.0.07 are included in Figures 1 and 2, respectively. A new predictive model for ground applications equivalent of a Tier II assessment will also be described at this symposium. Such tools for orchard applications have not yet been developed, but are under consideration, including a possible canopy interception model.

At Tier I Ground, the user can access default deposition curves based on SDTF field study data (reasonable worst-case conditions) based on droplet size classification, boom height, number of spray swaths and statistical percentile. The **Drop Size Distribution** classification includes two categories which were found to show significant separation in assessments of the SDTF data which actually covered four droplet size categories (Hewitt *et al.*, 1999). **Boom Height** includes the two heights that were tested in the SDTF field studies, 20 and 50 inches above ground. The model assumptions in individual swath contributions to total off-target deposition include considering statistical assessments of overlying data for each swath deposition profile. Selecting the number of swaths is an additional option however, accessed through **Extended Settings**. The model output in terms of 50% or 90% **Data Percentile** should be carefully considered because the latter is more likely to include outlier and high wind speed effects.

At Tier I Orchard Airblast, the user can select from one of five **Combination Orchard** orchard type grouping categories from those tested by the SDTF in field studies: *Normal* (stone and pome fruit, vineyard), *Dense* (citrus and tall trees), *Sparse* (young and dormant trees), *Vineyard* and *Orchard*. When selecting a category, information on the included components and spray accountancy is provided in the **Information** box. Under **Extended Settings**, the user can select and individual crop (tree) type and/ or the first and last tree rows which will be sprayed. This latter option is important because many applications are made to multiple rows of trees with a single pass, often avoiding applications to the outermost downwind tree row, to avoid drift from that row.

References

- Hewitt, A.J., Valcore, D.L. and Barry, T. (1999) The effect of droplet size and other variables on drift from applications of sprays by ground, *ASAE paper No. 991010, Toronto, Canada*.
- Teske, M. E., Bird, S. L., Esterly, D. M., Curbishley, T. B., Ray, S. L. and Perry, S. G. (2002) AgDRIFT: A Model for Estimating Near-Field Spray Drift from Aerial Applications *Environmental Toxicology and Chemistry* vol. 21, 659-671.

Modeling Workshop Abstracts

Figure 1. Tier I Ground Screen for AgDRIFT version 2.0.07

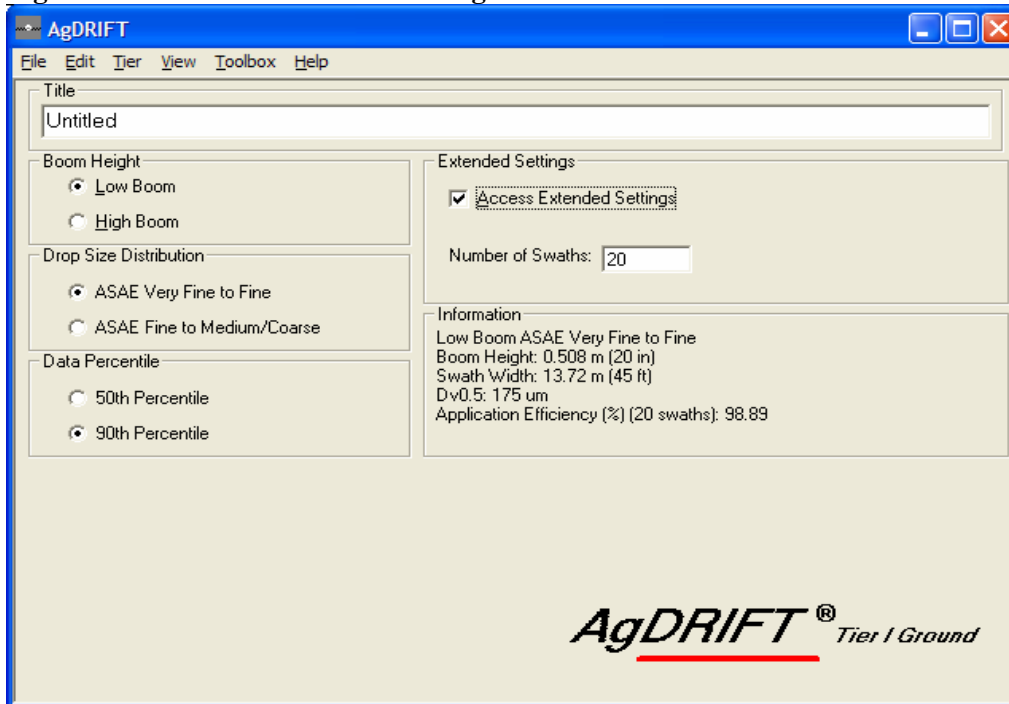
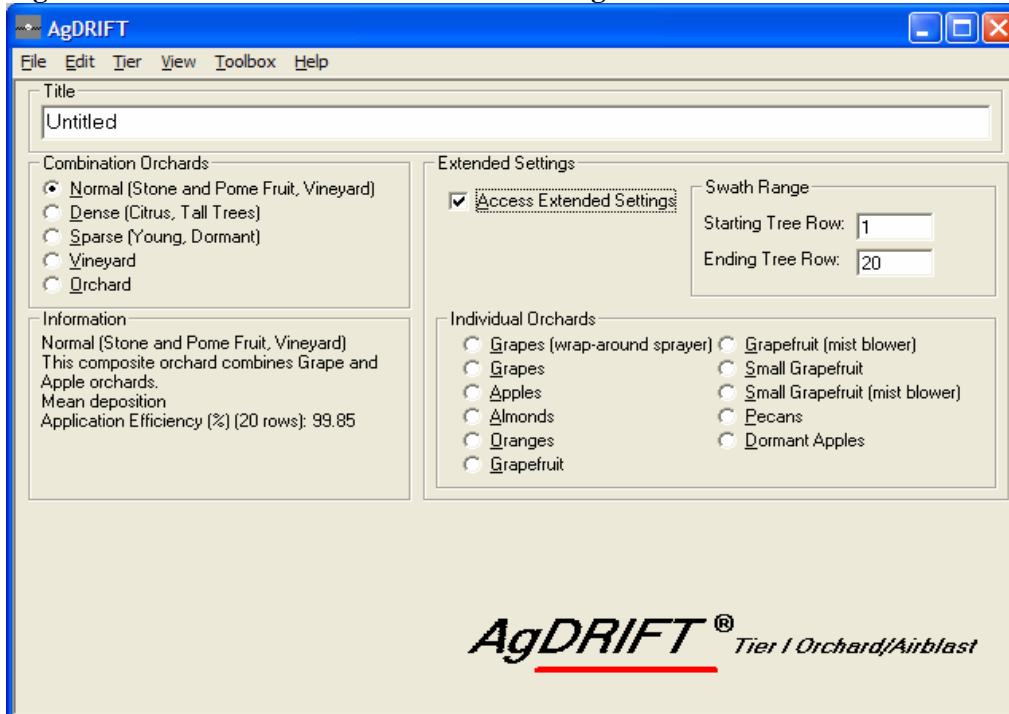


Figure 2. Tier I Orchard Airblast Screen for AgDRIFT version 2.0.07



Modeling Workshop Abstracts

German Drift Model for Field, Orchard and Aircraft

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Specialists of the BBA use the drift model to deduce official German regulations. It has the form of tables containing drift values in dependence on the distance from the field edge and reductions of drift. These reductions result from technological advance. The model is based on a large number of field trials containing the maximum variance of all imaginable parameter influencing the drift result. The model which is specified for field, orchard and aircraft has been developed through the multiple linear regression analysis with the help of the SAS® Program. Because of the non-linearity of the drift curve, the models are given in form of equations describing distance ranges. They describe a physical and a statistic relation, superposed by random effects. That means the model gives average values; reality could be different. An indication for the quality of the model is the coefficient of determination from 43% to 59 %. The development of the model is expensive because of the large number of field trials that are needed to meet the diversity of conditions and technical solutions. The consideration of the examined diversity of parameters is an integrated part of the model. Deviations at overlapping points of the cam segments of the drift curve exist. To ensure safety, it is recommended to use the higher value. Negative results of the drift curve are possible. This point and these in a higher distance on the same range should be set on zero.

Table. Influencing parameters to describe the model as a result of the multiple regression analysis

Field	Orchard	Aircraft
MVD	Gaps in the foliage	Psychometric difference
Psychometric difference	Height of the highest nozzle	Wind speed in drift direction
Vehicle speed	Difference of nozzle direction and tree	Hours since sun rise
Height of boom above plants	Air volume	Loading
Height of plants	Liquid volume	
Wind speed in drift direction	Type of sprayer (better: parameter)	This calculation is only for the special conditions in East Germany; Aircraft Z-37, circler slot nozzle, flight height of 2 m, aircraft speed of 130 km/h
Width of application	MVD	
Volume of liquid	Wind speed in drift direction	
Distance to field edge	Air temperature	
Neglected:	Psychometric difference	
Nozzle distance at boom	Hours since sun rise	
	Number of rows with one-sided application	
Plant height, field and beside	Distance to field edge	
	Vehicle speed	

The combination of input parameters depends on real technological possibilities and cannot be chosen without considering technological conditions. If given combinations are disregarded, the figure gives an impression of the great differences of drift caused by the diversity of influencing parameters and the possibility of drift reduction on field.

Modeling Workshop Abstracts

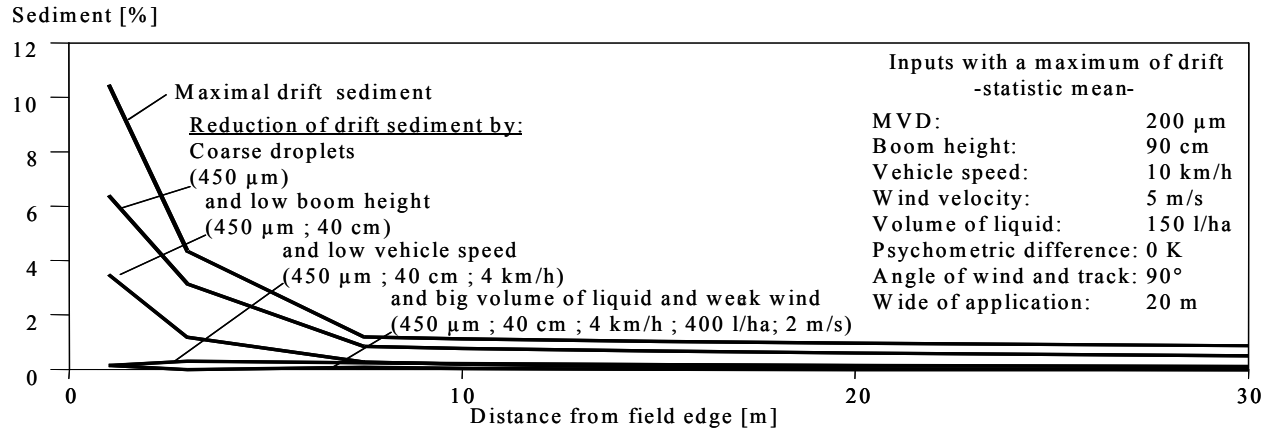


Figure: Reduction of the calculated drift sediment by advanced technology on field

AgDRIFT / AGDISP Ground Modeling

Milton E. Teske

Continuum Dynamics Inc.

This presentation will review the extension of the AGDISP and AgDRIFT aerial models to include a ground boom sprayer model. Built within the framework of the aerial spray model user interface, and able to access all of the features and options already present in these models, the development of a consistent mechanistic ground boom sprayer model becomes the next logical step in agricultural spray model development.

Several approaches have been explored to date – by other researchers – for simulating the ground sprayer process, from the relatively straightforward (the Tier I ground sprayer methodology in AgDRIFT, and multiple regression techniques found elsewhere, which work best when the application conditions are within the limits imposed by the data used to construct the regression) to the complex (running the general purpose CFD program FLUENT). In between is a non-mechanistic approach that culminated in the refinement of various random walk techniques, including several simplified modeling techniques that have proven useful when developing the physics-based model presented here.

Concurrent with preliminary model development, a large amount of field data has been collected for deposition and drift from ground sprayer operations, in an effort to quantify field effects and to provide data for model development and regulatory restrictions. The data set collected by the Spray Drift Task Force in two ground spray field trials conducted in 1992 and 1993 formed the foundation for the screening (Tier I) ground sprayer model programmed into AgDRIFT and the comparison basis of the simplified mechanistic model discussed here.

Basically, the aircraft wake effects were removed from AGDISP and AgDRIFT, and initial conditions are imposed on the jet flow exiting the nozzles. This jet flow is parameterized by its initial velocity, found from Bernoulli's law, and the inclusion of a model for the entrainment of the surrounding air by the spray exiting the nozzles. This entrainment effect supports and sustains the further movement of spray material toward the surface, and enables the model to make a highly accurate prediction of the SDTF data and, by the drift conference, the Canadian ground boom sprayer data as well. Inclusion of the entrainment effect

Modeling Workshop Abstracts

is seen as the central piece of physics needed to well represent what actually happens in a ground boom sprayer application.

DRIFTSIM -- A User-Friendly Computer Program to Predict Drift Distances of Droplets

H. Erdal Ozkan
Ohio State University

A Visual BASIC language computer program (DRIFTSIM) in Windows Version was developed to rapidly estimate the mean drift distances of discrete sizes 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 humidities (10-100%), wind velocities (0-10.0 m/s; 0-32.8 ft/s), droplet sizes (10-2000 µm), and 20% turbulence intensity. The program requires about 15.5 Mb of disk space. Variables can be either in metric or English units and input can be either individual droplet sizes or size classes with portion of volume in each class.

Note: A more detailed article regarding DRIFTSIM is included in the *poster article section* of this proceedings.

Modelling Canopy Interactions with Orchard Sprayers

Peter Walklate
Silsoe Research Institute, UK

Field studies of orchard spraying with axial fan equipment have shown that off-target drift contamination decreases significantly between the growth-stages of early-dormancy (i.e. worst-case drift conditions) and full-leaf development. This paper describes a modelling approach that links these changes in off-target drift contamination to the structural changes of the target canopy. The model utilises information about the range probability distribution of the target canopy. This information is derived from a tractor mounted LIDAR system that provides an idealised optical analogue of spray droplet transmission in the target canopy close to the sprayer. Results are presented to demonstrate how different dose adjustment strategies can be used to reduce drift during pesticide application at high risk conditions for early growth-stages. The information generated by this research is aimed at the development of practical drift mitigation strategies for broadcast air-assisted spraying of fruit orchards in the UK. (see poster article for more information)

Modeling Workshop Abstracts

Spray Advisor

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The Spray Advisor is an ongoing research and development effort of the USDA Forest Service and related cooperators. The Spray Advisor will encompass a wide array of modeling tools in support of planning and assessment of pest control spraying operations. Many of these spray support decision-making tools involve the use of spatially explicit input and output datasets. For this reason, a key feature of the Spray Advisor will be the ability to store, display, and analyze spatial model components through the use of Geographic Information Systems (GIS). The Spray Advisor will provide a user interface and means of visualizing spatial output based in the ESRI ArcGIS software platform.

The Spray Advisor will incorporate existing work in spray deposition modeling and software development by various groups including Forest Research (New Zealand), the Canadian Forest Service, Continuum Dynamics Inc., the University of Georgia, and the U.S. Department of Energy. Specific components of the Spray Advisor will include AGDISP (near-wake spray deposition), Baby BIOSIM (insect phenology), and SAGA (Spray Advisor Genetic Algorithm), among others.

This hands-on modeling presentation will demonstrate Spray Advisor functionality currently under development. This will include modeling of spray block and simple flight-line based spray deposition using AGDISP. The Spray Advisor interface also includes customized tools for analysis and query of deposition model results. The long term goal of the Spray Advisor development project as demonstrated is to provide spray managers with a comprehensive decision support toolbox, all designed to work with widely available GIS software.

Demonstration of SPRAYTRAN – A GIS-Based Atmospheric Dispersion Model for Estimating Spray Drift

Jerry Allwine

Pacific Northwest National Laboratory

The U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) has completed the development of a Geographic Information System (GIS)-based atmospheric dispersion modeling system, SPRAYTRAN (SPRAY TRANsport), for estimating the off-target drift of pesticides. The model development effort was funded by the U.S. Department of Agriculture Forest Service and the U.S. Environmental Protection Agency. SPRAYTRAN was developed in conjunction with another model development effort conducted at PNNL for the U.S. Department of Defense Strategic Environmental Research and Development Program (SERDP). A GIS-based dust dispersion modeling system (DUSTRAN) was developed for SERDP to be used at military testing/training ranges for predicting the impacts of range activities on particulate air quality. The SERDP and USFS/EPA model development programs had common elements, so both programs benefited from the concurrent development efforts.

SPRAYTRAN typically treats transport distances ranging from near the edge of a spray block to several kilometers downwind, but can treat transport distances of up to a few hundred kilometers. The modeling system is based on the Environmental System Research Institute's ArcMap 8.1 GIS and the EPA-approved CALPUFF dispersion model and the widely used CALGRID dispersion model. The CALMET

Modeling Workshop Abstracts

meteorological model provides the meteorological fields (e.g., winds, mixing height) for the CALPUFF and CALGRID dispersion models. AGDISP (a near field pesticide dispersion model incorporating aircraft wake effects, evaporation, gravity driven deposition etc.) is used as the source model that provides the properties (e.g., amount, particle size distribution, location) of driftable material from a pesticide spray application.

The SPRAYTRAN graphical interface allows the user to graphically define the location and size of the modeling domain and the spray block(s), and specify the time of spraying, duration of spraying, duration of the simulation, and source of meteorological data. The user interface also allows for the output from AGDISP to be imported into SPRAYTRAN. After execution of the dispersion model, the ground-level pesticide air concentrations and deposition fields can be displayed graphically. The pesticide plume can also be animated to see the progression of the plume across the modeling domain. The modeling system operates on a personal computer (including a laptop), works within the Microsoft Windows (95/98/NT/2000) operating system, and operates at any U.S. geographic location (provided the proper data files are present for the desired locations).

The SPRAYTRAN pesticide drift modeling system will be demonstrated at the Modeling Workshop and the modeling system will be available for hands-on use.

A Numerical Study of Near-Field Dispersion within and above Forest Canopies

Steve Edburg

Washington State University

Numerical simulations are being conducted to investigate the feasibility of Computational Fluid Dynamics (CFD) for predicting near field concentrations of a tracer gas within and above forest canopies. The current research is geared towards providing forest managers with a tool for developing anti-aggregation techniques to control the bark beetle; however CFD may be used for other environmental applications such as pesticide drift modeling.

Field experiments are often limited by cost, locations, meteorological conditions, etc. Numerical simulations are far less expensive and allow for many variations in virtually all flow parameters such as atmospheric stability, wind speed and direction, turbulence intensity, etc. The first step in modeling plant canopy dispersion or pesticide drift is predicting an accurate wind and turbulence field.

CFD codes provide numerical solutions to the equations governing fluid flow problems, over a finite grid. One benefit of CFD is the ability to capture a wide range of turbulent scales. The trunks in a forest canopy can be represented physically, or modeled, while also simulating the interactions of the entire atmospheric boundary layer. Another example is modeling the interaction of pesticide droplets released from an aerial nozzle with the wake of an aircraft or the interaction of the wake of the aircraft with the plant canopy and atmospheric boundary layer. However, these types of CFD simulations are very computationally expensive, and there always exists a trade off between computational expense and grid resolution.

As a first step, a CFD simulation has been used to study dispersion in a generic lodgepole pine forest canopy based on leaf area index (LAI) and stem density. Steady Reynolds Averaged Navier Stokes (RANS) solutions were computed using the k- ϵ and Reynolds Stress Model (RSM) turbulence closure models. These solutions provide insight on in-canopy dispersion; however they do not fully capture the dynamics of the flow. The current work is focusing primarily on Large Eddy Simulation (LES). LES

Modeling Workshop Abstracts

uses spatial filters to resolve large flow dominated eddies while modeling smaller eddies using a sub grid scale model. Unsteady LES, can be used to capture the dynamics of flow within a canopy, such features include large rolling eddies above the canopy, bursting and sweeping within the canopy, multiple shear layers, and drainage flows.

Current CFD capabilities and preliminary results from RANS and LES solutions will be shown for in-canopy dispersion of a tracer gas.

As applied to pesticide drift modeling, CFD may capture the local effects of nozzle spray and vortex wake interference of an aircraft, as well as droplet dynamics, drift, and deposition while encompassing the interaction with a non-homogenous plant canopy and the atmospheric boundary layer.

IDEFICS

J.C. van de Zande

Wageningen University and Research Centre – Agrotechnology & Food Innovations

The IDEFICS spray drift model (Holterman *et al.*, 1997) is a mixed 2-3-dimensional (2D/3D) random-walk model, which describes the trajectories of a large number of individual drops produced by a single nozzle. A complete boom sprayer is simulated by repeating these calculations for a representative set of nozzles along the boom. The distribution of downwind deposits in a cross wind is calculated as a function of distance from the edge of the crop. The vertical distribution, at a fixed distance downwind, is calculated as well.

Integrating twice Newton's second law of mechanics, the position of a drop can be calculated. The forces experienced by a drop are gravity, buoyancy and drag force due to local air velocity relative to the velocity of the drop itself. Gravity is calculated straightforward, and buoyancy can be neglected completely in this case. The drag force however changes continuously, since most parameters involved change with respect to location in space. Therefore the integration procedure must take place stepwise in time. During a certain time interval all parameters are considered constant. In the model the time interval is estimated based on the expected rate of change of the relaxation time of the drop.

In the spray cone below the nozzle air is entrained, which causes small drops to flow downward much more rapidly than estimated with respect to their sedimentation velocity. Modelling the spatial distribution of entrained air velocity and direction appropriately is considered an important base for a correct estimate of spray drift. Phase-Doppler anemometry (PDA) is used to measure the distribution of drop size and velocity in the spray cone. Entrainment is affected by wind speed, driving speed and the vicinity of the ground. In IDEFICS, the entrained airflow is modelled empirically based on the PDA measurements and patternator experiments. The effect of the vicinity of the ground, which obviously is impenetrable to air, is modelled by introducing an imaginary upward spraying nozzle below ground level. The entrained airflow caused by the imaginary nozzle is added to that caused by the real nozzle.

Near the nozzle the trajectory calculations are 3D. At a certain distance from the nozzle entrainment and driving speed no longer affect the trajectory, and the process essentially becomes 2D, so calculations can be turned into 2D.

The average wind velocity is assumed logarithmic with height above the ground. Turbulence is added as a locally random air velocity, its strength depending on local average wind velocity and atmospheric

Modeling Workshop Abstracts

stability. The turbulence velocity vector has random direction, and its length represents intensity. Inside the crop the wind profile has to be adjusted.

While falling or drifting through air, drop size decreases due to evaporation. It is assumed that only water evaporates as if the drop was of pure water. The ingredients are essentially involatile during spraying ('solid-core' phenomenon). If all water is lost before settling, the remaining 'dry' particle is assumed to stay airborne throughout.

Beside scenario studies the IDEFICS model is used in categorising nozzles for driftability (50,75,90 % reduction classes) under standard conditions.

IMAG Drift Calculator

J.C. van de Zande

Wageningen University and Research Centre – Agrotechnology & Food Innovations

The IMAG Drift Calculator is a tool to quantify spray drift to surface waters near a sprayed field or orchard. The calculator uses statistically obtained regression curves to calculate spray deposition next to the sprayed field.

The IMAG Drift Calculator has three major calculation units. The simplest unit is the first tier assessment as used in the Netherlands by the Board for the Authorization of Pesticides (CTB). This 'CTB drift table' roughly distinguishes spray drift from several arable and several tree crops. For fruit trees a further distinction is made with respect to growth stage (with or without leaves) and several specific application techniques.

The second unit ('Refined NL') accounts for four arable crops, bare ground, and fruit trees (in leaf and leafless). Also the effect of different (non-conventional) application techniques is accounted for.

Presently, the only water body onto which spray drift is estimated is a 'standardized Dutch ditch'.

The third calculation unit ('FOCUS-like') is similar to the 'Refined NL' unit. However, more crops can be selected, following a list of crops as used by the FOCUS Working Group on Surface Water Scenarios. Unfortunately, for most of these crops no regression curve for drift calculation is available. To overcome this problem, for each FOCUS-like crop an 'equivalent crop' is determined from the list of crops with regression curves (i.e. the crops in the 'Refined NL' scenario set). An equivalent crop is selected based on crop type, crop height and global canopy shape. For some crops no matching crop could be found, mainly because the FOCUS-like crop is too different from common crops in the Netherlands, or crop height is too large.

Currently, the IMAG Drift Calculator is limited to only four arable crops, two fruit crop stages, and bare ground. Non-conventional application techniques are only available for a potato crop. These cases imply a total of 12 regression curves. Future development will focus on a larger variety in crops and applications, and possibly varying weather conditions as well. Non-standard water bodies (e.g. user defined geometry) is a topic for future development also.

Modeling Workshop Abstracts

