Title:

A Probabilistic Exposure and Risk Model for Fumigant Bystander Exposures Using Iodomethane as a Case Study

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EXECUTIVE SUMMARY

Background

When pre-plant soil fumigants are applied, there is a potential for volatilization from the field following application. The fumigant vapor may drift downwind and cause exposures to bystanders that may be near the field. This report presents a model that can be used to accurately estimate the downwind concentrations following application, and can provide information that is useful for developing a risk assessment for bystander exposure. Additionally, the results from the model can be helpful in establishing buffer zones, restricted areas around the field after the application, which are designed to mitigate bystander exposure. The model is called the **P**robabilistic **E**xposure and **R**isk Model for **FUM**igants (or PERFUM). The model was specifically developed for the fumigant iodomethane, for which Arvesta Corporation, the sponsor of PERFUM, is currently seeking a registration. However, the model is sufficiently generalized that it may be useful for other fumigants.

Development of the PERFUM Software

The PERFUM approach utilizes historical meteorological datasets and provides a full characterization of the potential downwind concentrations. Specifically, for a given emissions profile, PERFUM calculates the downwind concentrations in all directions around the field for every day for a 5-year period (for each meteorological station). From these concentration calculations, the model establishes distances from the field, in all directions, before the concentration declines to a user-defined threshold goal. One method for establishing a buffer zone would be to define the buffer zone as an upper percentile of the distribution of these distances. The PERFUM software also provides a distribution of only the maximum daily concentrations, which could be used to establish a more conservative buffer zone. The core of the PERFUM modeling system is the U.S. EPA dispersion model ISCST3. The ISCST3 model (and its prior versions) has been used since the 1970s for air quality regulatory purposes.

The PERFUM modeling toolbox includes an additional program, PERFUM_MOE. The purpose of this program is to calculate a distribution of margins of exposure (MOEs) for a user-supplied buffer zone. This provides the user a tool to estimate the percentage of locations around the field where the concentrations are below the threshold at the buffer zone. Also, for locations where the concentrations may be higher than the buffer zone, the PERFUM_MOE provides an estimate of the MOEs. PERFUM_MOE is designed as a risk management tool.

Measurement of the Iodomethane Flux

One of the most important inputs to the PERFUM model is the estimate of the flux rate following application. Arvesta has, to date, sponsored seven studies to characterize the flux rate following an application. The basic design of the studies are as follows: iodomethane is applied to a field at a known application rate, and the concentration of iodomethane is measured at masts located in every direction around the field. CDPR has developed a back-calculation method using the ISCST3 model which was used to estimate the flux rate that best explains the measured concentrations. The flux studies were done for different application methods, as experience with other fumigants has shown that the application method affects the flux rates. Therefore, studies were conducted with the three proposed application methods: flat fume, raised bed, and drip irrigation.

A convenient way to express the results of a flux study is to present the percentage of the application that was emitted from the field during the first 24 hours. As will be discussed in this report, the key time period of interest for risk assessment for iodomethane is the first 24 hours. The results for six of the seven flux studies are presented in this report; the last flux study was recently completed and the results will be available before the Science Advisory Panel (SAP) meeting. Among the six studies analyzed to date, between 35% to 57% of the application mass was emitted from the field in the first 24 hours. The emissions were highest for the raised bed studies. Additionally, the flux rates during the daytime period following the application were typically higher than during the night. The PERFUM model explicitly incorporates the diurnal profile of the emissions to estimate the downwind concentrations.

Development of Meteorological Data

Typically, dispersion modeling applications use historical meteorological data collected by the National Weather Service (NWS) and prepared for modeling by the EPA's air office. However, most NWS data are collected at large airports and may not be representative of the more rural areas where fumigants are applied. Therefore, other sources of meteorological data were explored, including:

- *Automated Surface Observing System (ASOS)* data that are collected throughout the country by the Federal Aviation Administration (FAA) from automated collection systems at airports (both large and small). ASOS replaces the observer-collected systems.

- *California Irrigation Management Information System (CIMIS)* data that are collected by the California Department of Water Resources, and are used to support agricultural practices. CIMIS also uses an automated collection system.

- *Florida Automated Weather Network (FAWN)* data are collected by a consortium of groups in Florida, and is used to support agricultural practices. FAWN is an automated collection system.

From among these sources of data, 15 stations were chosen for analysis from among locations that were near the fumigant growing areas of California and Florida, which are likely the principal use areas for iodomethane. Due to the large amount of processing required to perform modeling analyses for all 15 stations, a few example PERFUM runs were performed for each of the 15 stations. From these example runs, a representative subset of four stations was chosen for the remainder of the analysis in this report. These stations include the Tallahassee, FL NWS station, the Bakersfield, CA ASOS station, the Ventura, CA CIMIS station, and Bradenton, FL FAWN station.

PERFUM Model Results

The PERFUM model was run using each combination of the flux data and meteorological data described above, and for five field sizes (1, 5, 10, 20, and 40 acres), for a total 120 model runs. The buffer zone estimates assuming the 90^{th} and 95^{th} percentiles of the downwind concentration distributions are summarized in Tables 5.1 and 5.2. The calculations were made assuming the maximum proposed application rate of 175 lbs/acre. Also, the calculations were made with the tentative toxicity threshold for iodomethane of 120 $\mu g/m^3$, which should change before the registration process is completed based on on-going research. Among the different flux study results, the average buffer zone estimates (among the four meteorological stations) assuming the 95^{th} percentile of the concentration distribution ranged as follows: (1) 1 acre: 154-273 feet, (2) 5 acre: 468-758 feet, (3) 10 acre: 725-1163 feet, (4) 20 acre: 1117-1777 feet, and (5) 40 acre: 1719-2761 feet. Assuming the 90^{th} percentile, the buffer zones estimates ranged as follows: (1) 1 acre: 102-180 feet, (2) 5 acre: 333-531 feet, (3) 10 acre: 517-821 feet, (4) 20 acre: 797-1266 feet, and (5) 40 acre: 1222-1952 feet.

One of the most interesting conclusions from the analysis was the significantly lower buffer zone estimates for studies where the application was completed in early morning compared to studies where the application was completed later. In typical practice, applications are conducted in the morning hours. This is ideal because the peak emissions occur during the daytime period that is most conducive to dispersion. However, in some of the flux studies, the additional activities associated with the measurements, resulted in later, and sometimes longer, application periods. Therefore, the application start time is an important factor in interpreting the results of the studies.

The PERFUM_MOE program was run for several examples using buffer zones established as both the 90^{th} and 95^{th} percentiles of the PERFUM concentration distribution. This analysis showed that the margin of exposure distribution for fumigant bystander exposure is relatively flat. Specifically, there is smaller distance between the 90^{th} and 95^{th} percentile values and percentiles beyond there than is the case for many environmental exposures.

Uncertainty Analysis

Section 6 of the report provides an uncertainty analysis for many of the key parameters. One the largest uncertainties in the analysis is the assumption that a person is at the perimeter of the buffer and outdoor for 24 hours. It is difficult to quantify the probability of this occurring, but it is expected to be low. Therefore, for most individuals, the buffer zone estimates are likely to be upper bounds.

1.0 INTRODUCTION

This purpose of this report is to describe the development of a modeling system to estimate health protective buffer zones for iodomethane (CH_3I). The modeling system is called the **P**robabilistic **E**xposure and **R**isk Model for **FUM**igants (or PERFUM). Arvesta Corporation (Arvesta) is currently requesting a registration for iodomethane with the U.S. Environmental Protection Agency (EPA) and the California Department of Pesticide Regulation (CDPR) for fumigant uses. Arvesta has sponsored the development of a buffer zone modeling system for iodomethane, which is described in this report. However, the model may be useful for other fumigants and has been developed in a generalized manner that could be applied to other fumigants.

Iodomethane is applied to agricultural fields by incorporation into the soil prior to planting. Following application, some of the applied iodomethane may volatilize from the field and be carried downwind, causing potential exposure to persons in the vicinity of the application. The highest exposures will be closest to the field, with the atmosphere dispersing the iodomethane gas to lower concentrations as the plume moves downwind. The purpose of a buffer zone is to establish a distance from the edge of the field where the concentration of iodomethane is at or below the safe level. The major factors that influence the required buffer distance is the flux rate of the fumigant[1], the meteorological conditions that influence gas dispersion, and the size of the field.

Currently, the only fumigant buffer zones have been established in California for methyl bromide by CDPR. However, it is expected that CDPR and EPA will establish buffer zones for other fumigants in the coming years. CPDR has the most historical experience in the development of buffer zones. For methyl bromide, CDPR has analyzed numerous studies to estimate the flux rate of methyl bromide for different application methods and field sizes[2]. CDPR has developed a modeling method to estimate buffer zones based on the measured flux rates (CDPR, 1997). The modeling methodology described in this report builds on the work done by CDPR to develop an alternative methodology, and applies this methodology to estimate buffer zones for iodomethane. The report also describes the development of the data needed

[1] The flux is defined as the amount of mass of the fumigant that volatilizes from the field per area of the field in a given amount of time.
[2] Many of the study reports are at this web address: http://www.cdpr.ca.gov/docs/dprdocs/methbrom/mebrmenu.htm.

to apply the modeling methodology, including the flux rates for different application methods and meteorological data that accurately represent the growing regions of California and Florida, where most of the applications are expected to occur.

The remainder of the report is organized as follows:

- *Section 2: Description of the PERFUM modeling system*: This section provides a background on the CDPR modeling methodology, and provides a description of the PERFUM modeling system developed for this study.
- *Section 3: Description of the iodomethane flux data*: Arvesta has sponsored seven studies, to date, that can be used to develop flux rate estimates. This section describes the studies and the methodology used to estimate the flux rates.
- *Section 4: Description of available meteorological data*: This section surveys the available meteorological data to represent atmospheric dispersion conditions in the growing areas where fumigants are most utilized, and describes how these data were prepared for dispersion modeling analysis. This section also describes how a subset of the available meteorological data was chosen for the detailed analysis presented in this report.
- *Section 5: Results of the modeling analysis*: This section provides the results of the modeling analysis, including the estimated buffer zones and margins of exposure at the buffer zone for different field sizes, application methods, and application rates.
- *Section 6: Uncertainty analysis*: This section describes and discusses the major areas of uncertainty in the modeling analysis.

Sections 3 and 4 are written for the reader who is interested in understanding the details about the input data used in the modeling analysis.

2.0 DESCRIPTION OF THE PERFUM MODELING SYSTEM

This section describes the new modeling system built for this study which is called the **P**robabilistic **E**xposure and **R**isk Model for **FUM**igants (PERFUM). The first part of this section describes the historical work done by CDPR on air exposure modeling for fumigants, for which the PERFUM system builds upon. The remainder of the section provides a general overview of the PERFUM system and capabilities. A more detailed description of the model software is provided in **Appendix A**, which should be read by potential users of the software.

2.1 Background on the CDPR buffer zone modeling approach and general principles of dispersion modeling

CDPR has done the most work to date related to fumigant buffer zones. For methyl bromide, CDPR has analyzed data from numerous volatility studies, and has developed estimates of the flux rate of methyl bromide following application for different application methods (see section 3 for a description of the methodology for estimating the flux rate). CDPR has developed a modeling methodology for developing a protective buffer zone for methyl bromide given a flux rate and a field size.

For most fumigants, emissions from fields decline sharply during the first several days after the application. Therefore, the peak exposures are typically during the first 24 hours following the applications, with only significantly lower exposures thereafter. For both methyl bromide and iodomethane, the relevant toxicological exposure period for acute risk assessment is 24 hours. Therefore, the buffer zone estimates were made based on 24 hour exposures.

To estimate downwind concentrations, CDPR uses EPA's Industrial Source Complex Short-Term, Version 3 (ISCST3) dispersion model. ISCST3 (and its prior versions) has been used by EPA and other regulatory agencies for air pollution regulatory purposes for over 20 years. ISCST3 is currently the EPA recommended model for most dispersion modeling applications (EPA, 1999a). Basically, a dispersion model can be used to estimate the downwind concentration of an air compound at any receptor point downwind (<50 km for ISCST3) given the emission rate (or flux rate) of the compound and a characterization of the meteorology in the atmosphere. For an area source, such as a fumigant application, ISCST3 requires the following information as input:

- The flux rate of the compound from the field for every time period of interest. The flux rate is defined as the amount of mass volatilized per unit area per unit time. Typical units of the flux rate are $\mu g/m^2/sec$ or lbs/acre/day. Section 3 discusses the estimation of the flux rates in detail.

- The dimensions of the field, and the coordinates of receptor points relative to the field dimensions where the concentrations are to be estimated. Also, the averaging period(s) for the concentration needs to be specified. For methyl bromide and iodomethane, the relevant averaging period for risk assessment is 24 hours. For this report, field sizes of 1, 5, 10, 20, and 40 acres were modeled, with represents the range of potential field sizes in agricultural practice. The development of the receptor grids for these fields is discussed later in this section.

- A characterization of the meteorological conditions affecting dispersion in the atmosphere. These parameters include the wind speed, wind direction, and the atmospheric stability. The atmospheric stability is a measure of the vertical mixing in the atmosphere, and is expressed with a 6-point ordinal scale, A-F. **Table 2.1** summarizes the definition of the stability classes using the classic Pasquill categories (as referenced in EPA, 2000). The scale ranges from A (strongly unstable) to D (neutral) to F (moderately stable). Higher stability classes disperse air compounds less rapidly, and result in higher concentrations. Section 4 discusses the development of the meteorological data used in the application of the modeling system that is presented in this report. However, the modeling system can be used with any adequate set of meteorological data.

A mixing height (or mixing depth) is also a required input. The mixing height is a vertical demarcation in the atmosphere that serves as an upper limit in the vertical mixing. The ISCST3 model assumes unlimited vertical mixing for stable conditions (E and F stability categories). However, for effects close to a ground-level source, such as a fumigant application, the mixing height is not an important parameter. This issue is discussed in more detail in Section 4.

Table 2.1. Pasquill Atmospheric Stability Categories

Surface Wind Speed (m/sec)	Daytime Insolation (function of the solar angle)			Nighttime Cloud Cover	
	Strong	Moderate	Slight	Thinly overcast or ≥4/8 cloud cover	≤3/8 Cloud cover
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Note: For overcast conditions during the day or night, the neutral category D should be used.

For regulatory modeling applications for EPA's air program, the ISCST3 model is typically run with five years of historical meteorology data to characterize the potential meteorological variability in a given source area. However, EPA air program modeling is typically done for a particular facility, whereas a fumigant application may occur in any part of the agricultural growing region of a state or the country. Therefore, it is more difficult to characterize the potential meteorological variability for fumigants.

For this reason and others, CDPR instead chose a standard meteorological condition to conduct its fumigant modeling for methyl bromide. CDPR's standard condition assumes a 1.4 m/sec wind speed, a C class stability (slightly unstable), and a constant wind direction for 24 hours (Johnson, 2001). This condition is represented as a conservative scenario that will assure protective buffer zones in most circumstances. To estimate a buffer zone for a given methyl bromide application method, CDPR uses the ISCST3 model with the flux rate for that application method (usually the average of several studies) and the standard meteorological condition. The ISCST3 output is analyzed to determine the maximum distance before the daily-average concentration falls below the threshold concentration for methyl bromide of 815 $\mu g/m^3$.

The CDPR standard condition does not represent an actual meteorological condition in the atmosphere. First, winds are virtually never from a constant direction for 24 hours. Also, a C class stability is only possible during the daytime; at night, the stability must be D, E, or F. Finally, a 1.4 m/sec wind speed is common during the nighttime, but is lower than most wind speeds during the daytime. Therefore, to evaluate the effectiveness of the standard condition for methyl bromide, CDPR conducted a modeling analysis with historical meteorological data from several stations in the California agricultural growing regions (Johnson, 2001). The results of this study found that the CDPR standard meteorological resulted in no exposures inside the buffer zone that were above the threshold concentration for approximately 95% of days in the historical meteorological data sets, with some variability depending upon the application rate and the field size. However, the CDPR methodology did not model diurnal variability of the application, which is an important factor for iodomethane that will be discussed later.

For iodomethane, EPA has tentatively established a threshold concentration of 120 $\mu g/m^3$, although this number is likely to change. The value for iodomethane is much lower than the CDPR value for methyl bromide, partly because of a difference in the method of derivation of the threshold between CDPR and EPA. If the CDPR buffer zone approach is applied to iodomethane with the EPA threshold concentration, it results in buffer zones of between 1000 to >4000 feet, depending on the application method and the field size. Buffer zones of lengths above 300 feet are generally not practical for agriculture, as it significantly limits the amount of agricultural land that a farmer can use for growing. Additionally, if the EPA method of estimating the threshold concentration is applied to methyl bromide, the CDPR modeling methodology would give buffer zones of 700 to >2000 feet, depending on the application method and the field size, which are also not market viable.

The results described above have motivated the exploration of alternative procedures to estimate downwind concentrations.

2.2 Framework for the PERFUM system

The major drawback of the CDPR approach is its use of the standard meteorological condition. The condition does not represent an actual meteorological situation and cannot be used to estimate the actual probability of being exposed above the reference concentration. Furthermore, it cannot account for the diurnal variability in flux rates, which is a potentially critical factor in estimating the buffer zones, as will be discussed later. Therefore, the most important aspect of a next generation model would be the capability to use actual meteorological data.

The purpose of the PERFUM approach is to get closer to an estimate of the probability of exposure for someone at the perimeter of the buffer zone. Therefore, risk managers could know that for a given buffer zone, a person at the perimeter of the buffer zone would be exposed to a concentration less than the reference concentration a certain percentage of the time. The phrase "closer to an estimate of the probability of exposure" is important to bear in mind. For several reasons that are discussed in the report, the concentration estimates at the buffer perimeter are upper-bound, conservative estimates of exposure, and thus it is not a true probability of exposure.

It is not the purpose of this report to establish a percentile of regulation for risk managers, but simply to offer an approach for estimating the exposure probability that can generate scenarios of interest to risk managers. However, for the purposes of discussion in the report, we will define the percentile of regulation as either the 90th or 95th percentile, which are common, conservative metrics used by the Agency.

The CDPR approach focuses on the maximally exposed location for each set of meteorological conditions[3]. In other words, for a given set of 24-hour meteorological conditions, the CDPR approach considers only the location at the farthest distance from the field that is equal to the threshold concentration. Essentially, this represents a 100th percentile on a daily basis. The approach that is developed in this report builds upon the CDPR approach to consider all of the locations around the field, instead of only the maximally exposed location. With this approach, a distribution is established that considers all of the locations around the field, and calculates an upper percentile of this larger distribution to estimate the buffer zone. This approach more closely approximates a probability of exposure for someone at the perimeter of the buffer zone (although we are speaking about locations, where there may not be a person). CDPR explored the use of this technique in its attempts to validate its buffer zones for methyl bromide using the CDPR standard meteorological condition (Johnson, 2001). **Table 2.2** summarizes the goals of each of the approaches.

[3] It is important to think of "locations" instead of "exposures," because, for a given field, it is unknown whether an individual will actually be at the location around the buffer zone that has the highest concentrations.

Table 2.2 Goals for CDPR and PERFUM Approaches

CDPR Approach	Set buffer zone based on minimizing the probability that the location in the peak downwind portion of the plume has a concentration greater than the threshold.
PERFUM Approach	Set buffer zone based on minimizing the individual probability of any location at the edge of the buffer zone, in any direction from the field, has a concentration greater than the threshold.

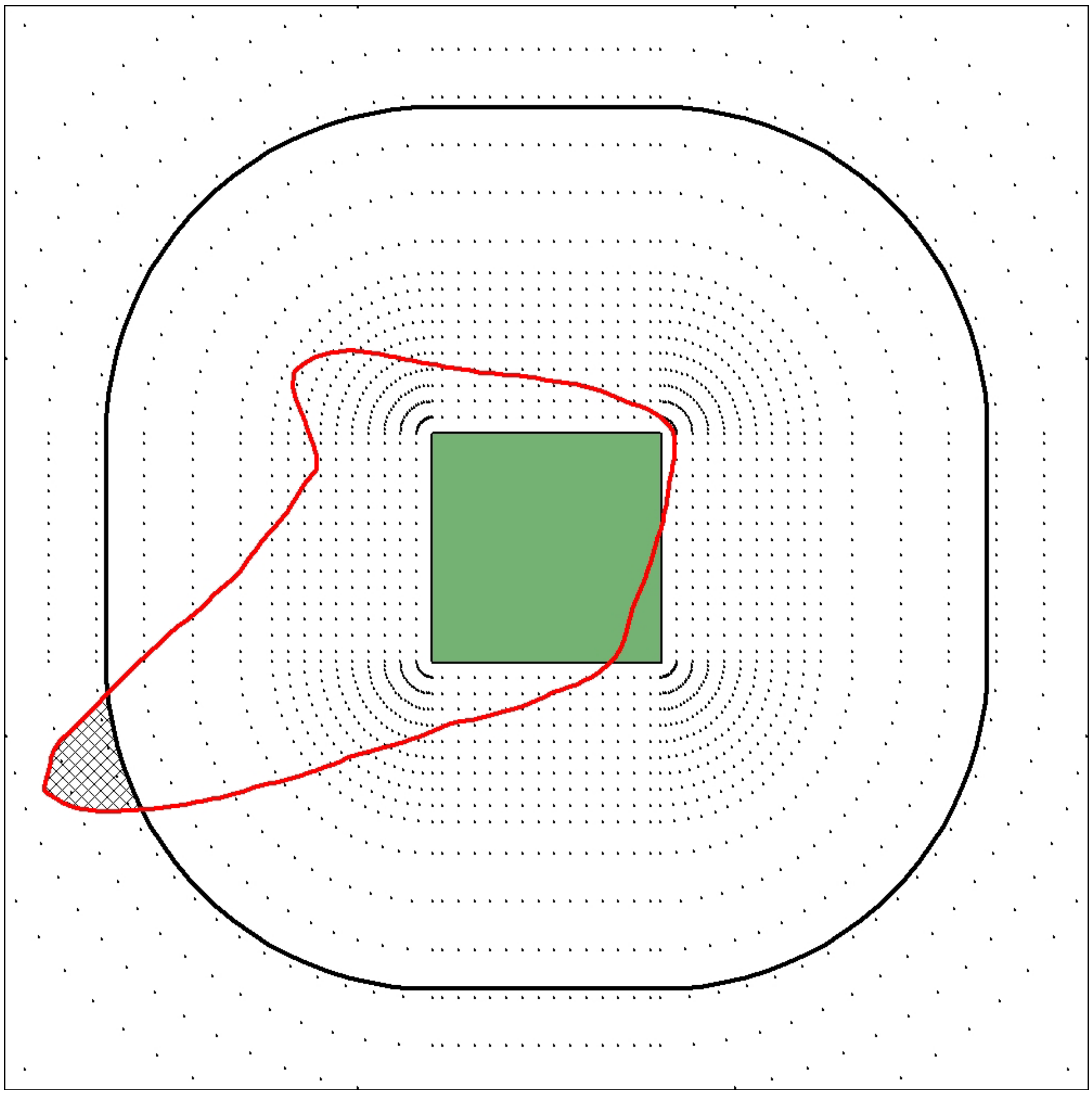
The PERFUM approach is illustrated in **Figure 2.1**, which is the actual output of the model for one day for a 5 acre field. For a typical day, such as the one selected for this example, the buffer zone is defined such that the concentration at the perimeter of the buffer zone is at or below the reference concentration for 95% of the perimeter length. Assuming an equal probability of a bystander being located in any direction around the field, the concentration estimate at the perimeter represents an upper-bound probability of exposure. The assumption of equal probability in location will likely not be true for individual fields, but should be true, on average, across the many fields where applications will occur. The concentration estimate represents an upper-bound for exposure for several reasons, including the following:

- There is not necessarily someone at the location of the maximum concentration.
- A person may not spend a total of 24-hours at the perimeter of the buffer, and thus would have a lower 24-hour average exposure than is estimated by this approach.
- The indoor concentrations may be lower than the outdoor concentrations, which is not accounted for with this approach.

In Figure 2.1, the contour line shows the distance from the field for the concentration to reach 120 $\mu g/m^3$ in all directions. As is shown, the buffer zone perimeter is defined as the buffer zone required for 95% of the perimeter of the buffer to be at or below the reference concentration (for simplicity, this example only uses one day of

Figure 2.1. Example Concentration Estimates for a 5 Acre Field

(Red line shows contour at reference concentration; black line shows the buffer zone).



meteorological data, but the actual calculations will use 5 years). The shaded area in the figure represents the area beyond the buffer zone where bystanders could potentially be exposed above the reference concentration. Although, the modeling system includes a program to estimate how far above the threshold any exposures could be, which will allow risk managers to account for this in making policy decisions. The CDPR approach would define the buffer zone in this example from the point along the 120 $\mu g/m^3$ contour that is farthest from the field. For other days, this example would look different, and the difference in buffer zones from the CDPR approach and the approach presented in this report could be larger. In turn, for many other days, there would be no exceedances of the threshold beyond the buffer zone.

The modeling system also outputs the buffer zones using the CDPR methodology, as would be applied in a probabilistic approach. Specifically, the model estimates the maximum distance to the reference concentration for each day, regardless of the direction from the field and outputs the distribution of these values for comparison and risk management purposes.

Another way to think of the difference between the CDPR and the PERFUM approach is as follows (assuming 95% for the percentile of regulation):

- <u>CDPR approach</u>: If a person were placed on a random day at the location along the perimeter of the buffer zone with the <u>highest concentration</u>, there would be approximately a 95% chance that the concentration at that location would be below the threshold concentration.

- <u>PERFUM approach</u>: If a person were placed on a random day at a <u>random location</u> along the perimeter of the buffer zone, there would be approximately a 95% chance that the concentration at that location would be below the threshold concentration.

2.3 Development of the PERFUM modeling system

2.3.1 Motivation for the development of PERFUM

The core of the PERFUM modeling system is the U.S. EPA dispersion model ISCST3. The ISCST3 model (and its prior versions) has been used since the 1970s for air quality regulatory purposes, and is based on the classic Gaussian dispersion modeling approach. The model was designed for the EPA Office of Air & Radiation, and the options for outputting the data were chosen to meet air program regulatory requirements. For example, the model can output the highest and second highest concentrations in a given period at any receptor site, which are often values of interest in permitting applications. However, the model is not designed to easily determine a buffer zone for a fumigant, with either the CDPR or PERFUM approach. The model calculates all of the necessary concentration predictions to perform these calculations, but it is necessary to develop additional coding to perform the buffer zones calculations.

2.3.2 Incorporation of ISCST3 into PERFUM

The original PERFUM system called for the user to first run ISCST3 and generate a file of the 24-hour concentration predictions at receptor sites around the field. Following the ISCST3 run, the user would run the PERFUM model which would read the ISCST3 output file and perform the necessary buffer zone calculations. Thus, PERFUM essentially operated as an ISCST3 post-processor. However, there were several disadvantages to this approach:

- The ISCST3 output files were particularly large (up to 1GB for a 40 acre field), which created issues related to file storage space.

- It was not possible to estimate the 24-hour average concentration for periods other than midnight to midnight without outputting the hourly results, which was infeasible due to storage space and run time issues.

- The model was relatively slow due to the large amount of time required for ISCST3 to write the output file to the disk, and for PERFUM, in turn, to read the ISCST3 output data from the disk.

- The hourly flux rates could not be treated as a probabilistic variable.

These issues were solved by incorporating the ISCST3 program into PERFUM. ISCST3 was developed in FORTRAN with the same FORTRAN compiler used to develop PERFUM (Lahey 95). EPA provides the FORTRAN source code for ISCST3 and it was relatively easy to compile it with the Lahey 95 compiler. To develop PERFUM, the ISCST3 program was modified into a subroutine that is called from within PERFUM. In turn, as ISCST3 calculates the downwind concentrations, calls to subroutines within PERFUM were added to make the buffer zone calculations. In this way, the calculations are made "on the fly" and there is no need to store all of the concentration data in memory (which would be infeasible or impossible) or to write out a large output file. All modifications that were made to the ISCST3 model are documented in **Appendix A**.

Although ISCST3 is run as a subroutine in PERFUM, it still runs in basically the same manner and the user has all of the flexibility inherent in ISCST3 (at least insofar as modeling an area source). The user needs to generate an ISCST3 input file, as they normally would. The ISCST3 program is run in its regulatory default model with rural flat terrain. We are running the model for 5 years of meteorological data for a different reason than the EPA Office of Air & Radiation which typically runs the model for 5 years of data for permitting applications. In most air office applications, the source is continuously emitting and the model is run to generate a 5-year time-series of concentration estimates. However, fumigants are generally applied about once per year. In this application, we are essentially running the model in a probabilistic mode to generate a distribution of daily average concentrations over a 5-year period that represents the possible range of downwind concentrations depending on when the fumigant is actually applied. If one assumes that there is an equal probability of a fumigant application occurring for any day of the year (a simplification, which is not necessarily true), the daily average concentration distribution generated from a 5-year run could be used to develop a probability of exposure. One model run is required for each combination of the flux rate profile, meteorological station, and field size. Appendix A also describes files that can be used to run PERFUM and PERFUM_MOE in a batch mode (i.e., perform multiple runs sequentially).

Another important aspect of the approach is the use of the actual hourly flux profile from the flux studies. Specifically, the ISCST3 model allows the flux rate to vary by hour-of-day. Therefore, the flux estimates from each period of the studies (periods range from 2 to 12 hours) are input into the model for the particular hour-of-day that the period measurement occurred. This allows the model to account for the day-night variability in flux rate, and account for the higher fluxes during the day than typically occur for morning applications, which are the norm. The conditions for dispersion are most conducive during the daytime, and the flux rates are highest during the daytime, particularly for a morning application. Therefore, the use of diurnal flux rates represents an important refinement that will increase the accuracy of the downwind concentration estimates.

The ISCST3 subroutine was run assuming rural, flat terrain, consistent with most agricultural applications. The model was run in regulatory mode, which includes the use of the calms processing routine.

2.3.3 Probabilistic treatment of the flux rate

The flux rates are also treated as a probabilistic variable with an uncertainty developed from the statistical bounds of the flux calculation (see Section 3 for details). For each measurement period in the flux studies (typically of 2 to 12 hour duration), a standard error is generated that reflects the measurement uncertainty of the flux rate (see Section 3 for details of the standard error calculation). The model perturbs the concentration estimates within each period by the standard error using Monte Carlo methods to simulate the uncertainty in the flux estimates (the flux and concentration are linearly related, thus perturbing the concentration is equivalent to perturbing the flux). Essentially, for each period for each simulated day, the PERFUM model probabilistically calculates an adjusted flux rate by adding a deviation (which could be positive or negative) defined from the distribution of standard errors:

$$Flux_{adj} = Flux + \left(\frac{CV\%}{100}\right) * Flux * t_{df=11} \qquad (3\text{-}1)$$

where the *CV%* is defined as the coefficient of variance (as a percent), which is the standard error divided by the flux rate estimate, $t_{df=11}$ is a randomly generated *t-value* from a distribution with 11 degrees of freedom (most of the flux studies have 12 masts, so the standard error of the regression has 11 degrees of freedom). In the actual model, the perturbations are performed with the concentration estimates, taking advantage of the 1:1 proportionality between the concentration and flux. A file of random *t-value*s was generated in Microsoft Excel® with the *TINV* function. It is useful to define the standard error as a *CV* so it can be applied for different application rates.

2.3.4 Development of the receptor grid for estimating buffer distances

To estimate buffer zones, we need to estimate concentrations with the ISCST3 model at various distances from the field to accurately determine the distances in each direction before the concentration is below the reference concentration. These calculations are based on the current EPA estimate of the threshold concentration of 120 µg/m^3 averaged over 24 hours. This methodology can be applied to a different value if the reference concentration changes. In fact, the threshold concentration is an input to the model that can be changed by the user. ISCST3 allows the user to establish a receptor grid of data points around a source in which the concentration is estimated (in this case, on a daily average basis). We developed appropriate receptor grids in a GIS program and imported them into ISCST3. As an example, the receptor grid for a 5 acre field is shown in **Figure 2.2**. The grid establishes receptors surrounding the field in 28 rings with the following distances from the edge of the field: 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 150, 180, 210, 240, 270, 300, 360, 420, 480, 540, 600, 720, 840, 960, 1080, 1200, 1320, and 1440 meters. The spacing is similar, but not identical, for the other field sizes. From the sides of the field, adjacent receptors in each of the 28 rings were placed approximately 10 meters apart. At the corners, receptors for each ring were placed at 5 degree angles. The receptors were placed such that there are spokes representing a set of points starting from a location on the field that includes a receptor in each of the rings. The blue line marked on Figure 2.2 represents an example of a spoke. The model software includes both a coarse and fine grid option. With the coarse grid, the model runs much faster (by about a factor or four), but the estimates above the 99th percentile are less accurate. For most applications, the coarse grid system is adequate, but the fine grid files are provided if the user desires more accurate estimates above the 99th percentile. The spokes, rings, and receptor points for each field size for both the fine and coarse grids are summarized in **Table 2.3**.

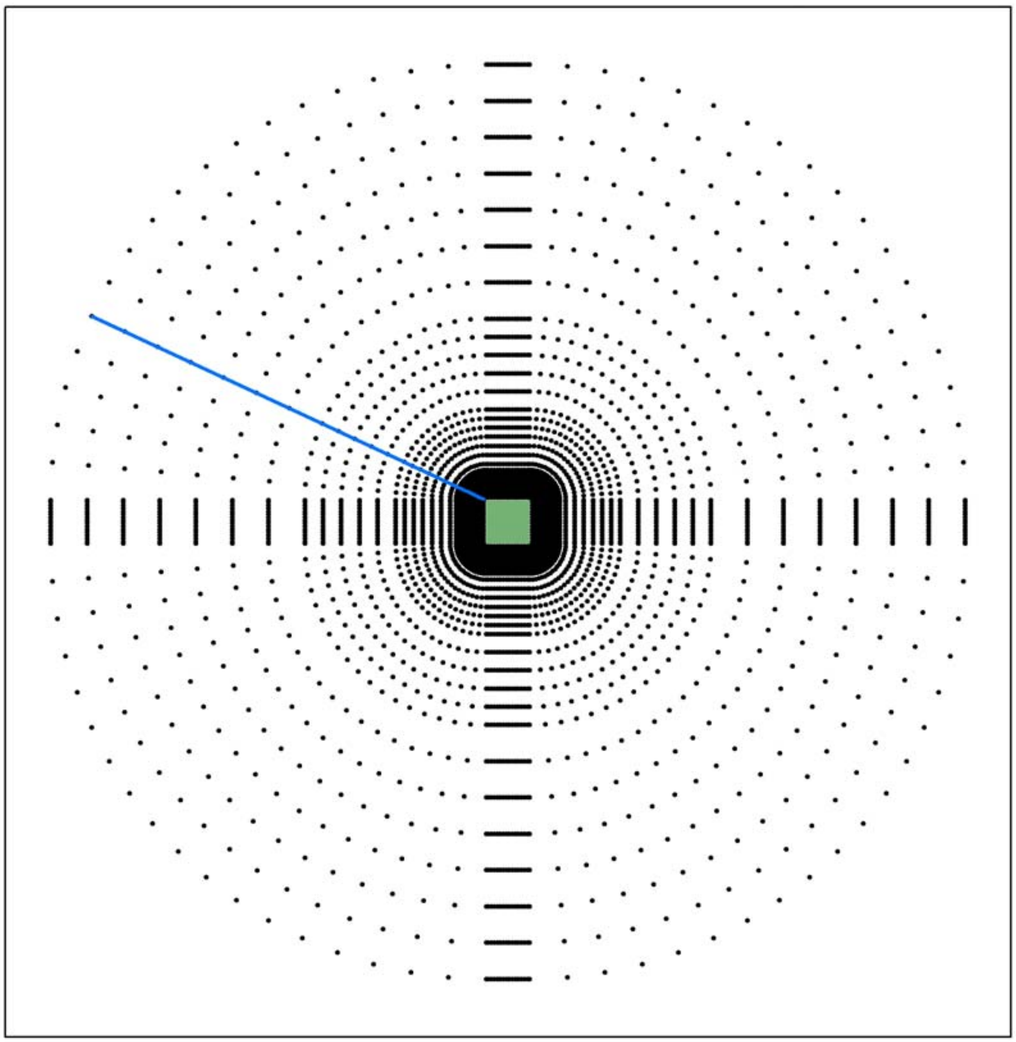
All receptors were defined at 1.5 meters above the surface, which represents a typical breathing height for a person.

Table 2.3. Receptor Points for Various Field Sizes

Grid Type	Field Size (acres)	Number of Spokes	Number of Rings	Number of Receptors (Spokes*Distances)
Fine	1	96	28	2,688
	5	132	28	3,696
	10	152	28	4,256
	20	188	28	5,264
	40	232	28	6,496
Coarse	1	24	28	672
	5	33	28	924
	10	38	28	1,064
	20	47	28	1,316
	40	58	28	1,624

Figure 2.2. Receptor Grid for a 5 Acre Field

(5 acre field in center; blue line is an example of a spoke)

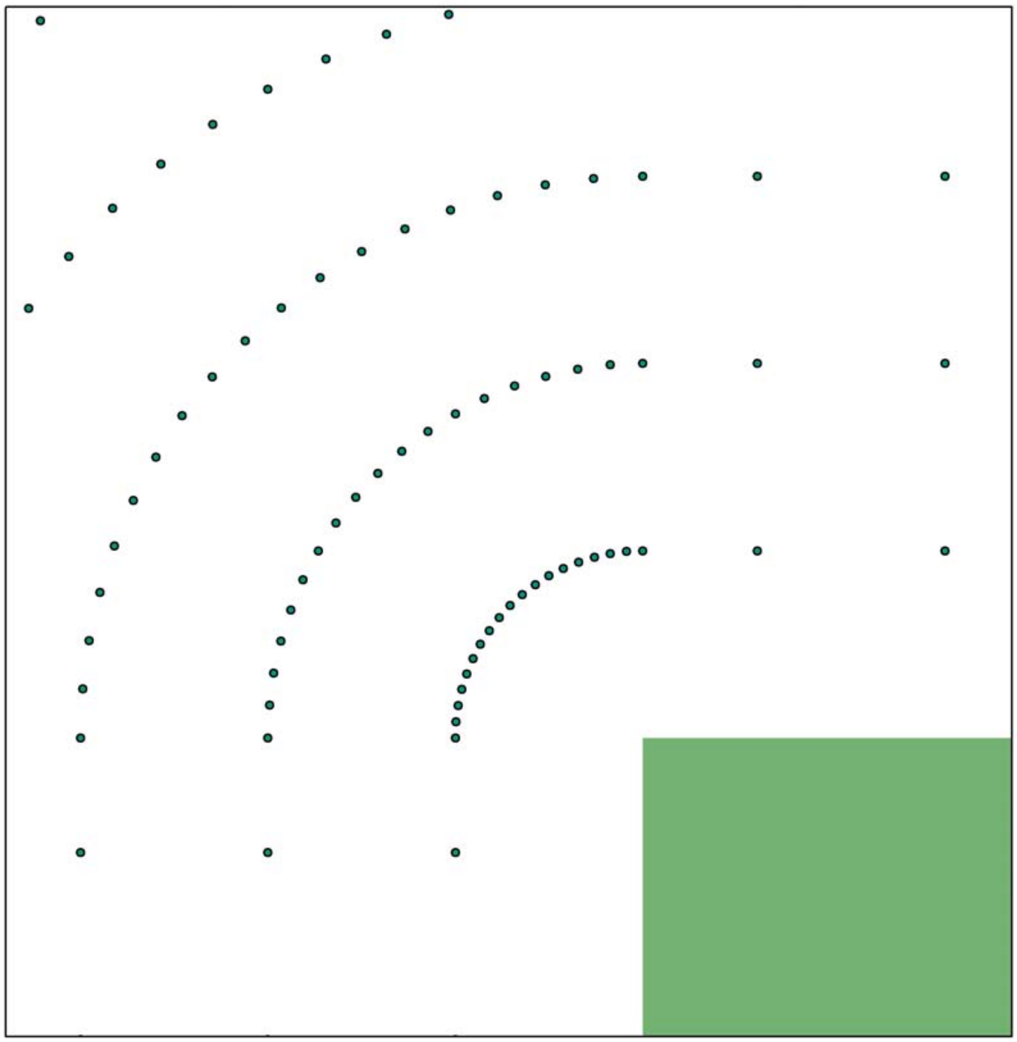


Several sensitivity tests were conducted to examine the differences between the coarse and fine grids. The coarse grid calculates the buffer distances at the 99th percentile and below within a few meters of the fine grid estimates. At the 99.99th percentile, the difference is only about 2 meters. The error can be larger using the CDPR approach of defining the distribution as only the maximum daily concentrations. However, for the 95th and 99th percentile, the coarse grid results were within about 5 meters of the fine grid (though the coarse grid underestimates). At the 99.99th percentile, runs with the coarse grid underestimates buffer distances with the maximum concentration approach by as much as 35 meters in the tests that were conducted.

The receptor grid is similar to the approach taken by CDPR for its methyl bromide buffer zone validation analysis. The advantage of this approach is that it is possible to conduct a cubic spline interpolation for each spoke to get a more exact estimate of the buffer distance[4]. The use of this approach unavoidably results in a receptor grid that is more dense is some places than others. For example, the grid is denser at the corners for small buffer zones, and denser on the sides for large buffer zones. **Figure 2.3** shows a blown up version of Figure 2-2 along the northwest corner. It shows that near the field the receptor density is greater along the corners than the sides of the field. Thus, if the winds were blowing across this corner, more points may exceed the threshold concentration than would have if the winds were blowing across the side of the field, all else being equal. Therefore, equal weighting of each point may cause a small bias. To investigate this bias, the perimeter distance that each point represents, defined as the distance between the midpoints for a point compared to its two adjacent points, was estimated within the program. This perimeter distance was included as a weighting factor in the calculations. The weighting factor for a point was defined as the ratio of its perimeter distance point divided by the average perimeter distances of all of the points in the respective ring. The use of the weighting factor did not significantly impact the buffer zones (typically only a 1-3 meter difference from the un-weighted values). Therefore, the weighting factor was not included in the final version of PERFUM.

[4] In other words, the interpolation provides an estimate of the exact distance where the concentration equals the reference concentration, between two adjacent points above and below the threshold concentration.

Figure 2.3. Blow Up of the Northwest Corner of a 5 Acre Field



2.3.5 Output of PERFUM

The PERFUM program outputs the following information:

- The percentile distribution of the buffer lengths using the PERFUM approach including all of the distances around the field, and the CDPR approach of only including the maximum daily concentration. Percentiles are included from the 1st to the 99th percentile, in increments of one percentile, plus the 99.9th and 99.99th percentiles.

- The percentile distribution can be output for up to 10 user-specified application rates. This is a useful tool because the permit buffer zones in California are a function of the application rate.

- The program outputs the buffer lengths on a monthly basis to assist in seasonal analysis. This could be helpful in locations where the seasonal pattern of application is well understood.

- The ISCST3 subroutine within PERFUM also produces the normal ISCST3 output file, which the user should review to see if there were any errors or warnings in the ISCST3 run.

- The model includes about 60 error messages that identify potential problems in a model run and halt execution. The model also outputs a list of warnings that occurred during the run within PERFUM (not including the ISCST3 subroutine). A list of errors and warnings and potential solutions is found in Appendix A.

2.3.6 Margin of Exposure Program

As part of the PERFUM toolbox, there is a program called PERFUM_MOE, which estimates the distribution of the margins of exposure for someone at the perimeter of the buffer (assuming they are at the perimeter and outdoors for 24 hours). For the purposes of this report, the margin of exposure (MOE) is defined as follows:

$$MOE = \frac{No\,Observed\,Effect\,Level}{Exposure} \quad (2\text{-}1)$$

where the No Observed Effect Level (NOEL) is from an animal study. Typically, EPA requires an MOE in risk assessment when animal studies are used.

The PERFUM_MOE model uses the buffer length estimate from PERFUM, or any other buffer length that the user is interested in. As with the buffer lengths, percentiles are included from the 1st to the 99th percentile, in increments of one percentile, plus the 99.9th and 99.99th percentiles, and the maximum. The margin of exposure is typically defined as the no observed effect level (NOEL) divided by the exposure. Thus, the MOE essentially provides an estimate of the number of fold that the NOEL is above the exposure estimate. It should be noted that the U.S. EPA and CDPR have different methodologies to determining the human-equivalent NOEL for iodomethane, so the MOEs will need to calculated separately for both NOELs. If one only wants the buffer zone estimate, this program does not need to be run. The purpose of this program is to provide additional information for risk management.

3.0 DESCRIPTION OF IODOMETHANE FLUX DATA

3.1 Background on CDPR Methodology for Calculating Flux Rates

CPDR has developed a modeling methodology to estimate the flux rate of a fumigant from a field following application based on measurements of the concentration of the fumigant around the field (Johnson et al., 1999). It has been primarily used for methyl bromide. While field measurements of downwind concentrations provide reasonable estimates of exposure around the field for a particular application, the observed concentrations are dependent upon the field dimensions and the particular meteorological conditions that existed following the application. The flux rate estimate derived from the CDPR methodology can be used to generalize the results of individual field measurements to predict potential downwind concentrations under different field dimensions and meteorological conditions, and to determine if a protective buffer zone is necessary. Also, the methodology can be used to estimate the total percentage of the application that was emitted from the field.

The CDPR methodology employs the ISCST3 model (EPA, 1995). ISCST3 provides predictions of the concentration of an airborne compound downwind following a release, and, for this application, requires the following input data:

- The flux rate of the compound (i.e., the amount of mass of the compound that is being emitted from the field per unit time for a given area).
- For an area source such as the emission of a fumigant from a field following an application, the model requires the geographical dimensions of the field.
- The meteorological conditions during the modeling period, including wind speed, wind direction, and atmospheric stability.

In this application, the downwind concentrations have been measured, and the objective is to determine the flux rate of the compound. Therefore, the ISCST3 model is used to "back-calculate" the flux rate.

The goal of the back-calculation is to determine the flux rate that best explains (statistically) the observed measurements. The ISCST3 model is run using a nominal flux rate (chosen, in this case, to be 100 $\mu g/m^2/sec$), and programmed to estimate the air concentration of the fumigant at each of the measurement locations. Even if the nominal flux rate does not end up being the correct flux rate, it is not necessary to run the model again because the flux rate and the predicted concentrations are exactly proportional (e.g., a doubling of the flux rate results in a doubling of the downwind concentration). Therefore, given the results of a single model run, the concentrations at the receptors can be determined for any flux rate by multiplying the nominal concentration by the ratio of the flux rate and the nominal flux rate. Instead, the predicted concentrations at the measurement locations are statistically compared with the measured values to estimate the actual flux rate.

CDPR uses a linear regression (including both a slope and intercept) to compare the predicted concentrations (using the nominal flux rate) and measured concentrations at the receptors, as follows:

$$Y_{meas} = mX_{ISC} + b \tag{3-1}$$

where Y_{meas} is the matrix of measured concentrations, X_{ISC} is the matrix of ISC-predicted concentrations, *m* is the linear regression slope and *b* is the linear regression intercept. The estimated flux rate for a measurement period is determined by multiplying the linear regression slope by the nominal flux rate as follows:

$$Flux_{est} = m * Flux_{nominal} \tag{3-2}$$

Sometimes the linear regression with slope and intercept does not provide an adequate result. For example, the intercept term in the regression cannot be used in the estimation of the actual flux rate because the predicted concentrations using ISC are multiplicatively proportional to the flux rate. Therefore, the CDPR methodology requires a test of the statistical significance of the intercept term of the linear regression. If the intercept is statistically significant or is large compared to the measured concentration, the resulting estimate of the flux can be biased, usually low. CDPR suggests a number of options when the linear regression with slope and intercept does not provide an adequate result, including sorting the measured and modeled values independently and conducting a linear regression constrained through zero (i.e., no intercept). For this study, a linear regression of the data was performed first. A linear regression of the independently sorted data was performed if any of the following occurred with the initial regression: (1) the intercept was statistically significant, or (2) the r^2 was less than 0.5. If any of those conditions were not achieved with the linear regression of the independently sorted data, a linear regression constrained through zero of the sorted data was used.

The correlation coefficients of the regressions ranged from 0.76 to 0.97 for the periods immediately following the application in the studies that were analyzed. **Figures 3.1 and 3.2** show examples of the model versus monitoring data fits that represent the opposite ends of the spectrum of good and poor fits. Figure 3.1 shows the results for the first period of the Camarillo drip irrigation study. The original regression of the raw data had a good fit but the intercept was statistically significant. Therefore, consistent with the CDPR-recommended method, the data were sorted and fit with the intercept constrained through zero. Figure 3.1 shows the excellent agreement between the measured and modeled data.

Figure 3.2 shows an example where the linear regression fit was relatively poor. The measured concentrations in three of the four directions around the field were relatively similar, but the model predicted different concentrations in each of these directions. Nonetheless, the regression fit does predict the peak concentrations relatively well. One possible reason for the poor fit was that this study, unlike the others, included only one measurement period for the daytime period following the application.

The linear regression analysis can also be used to estimate the measurement error for each flux estimate. The regression analysis produces a standard error for the slope estimate which represents an uncertainty for the slope. To apply the error estimate with different application rates, it is useful to express the standard error as a coefficient of variance (*CV*), which is defined as the standard error divided by the flux estimate as follows:

$$CV = \frac{\sigma_{err}}{Flux_{est}} \tag{3-3}$$

The *CVs* will be provided for each measurement period, and are incorporated into the modeling system in a probabilistic manner. It is important to note that the measurement error for a given study does not necessarily reflect all of the potential variance that exists for the flux rates. A variety of site-specific factors are also relevant such as the ambient temperature, soil temperature, and soil type. These factors are discussed in the uncertainty analysis in Section 6.

Figure 3.1. Comparison of Measured and Modeled Estimates for the First Period for the Camarillo Drip Irrigation Study

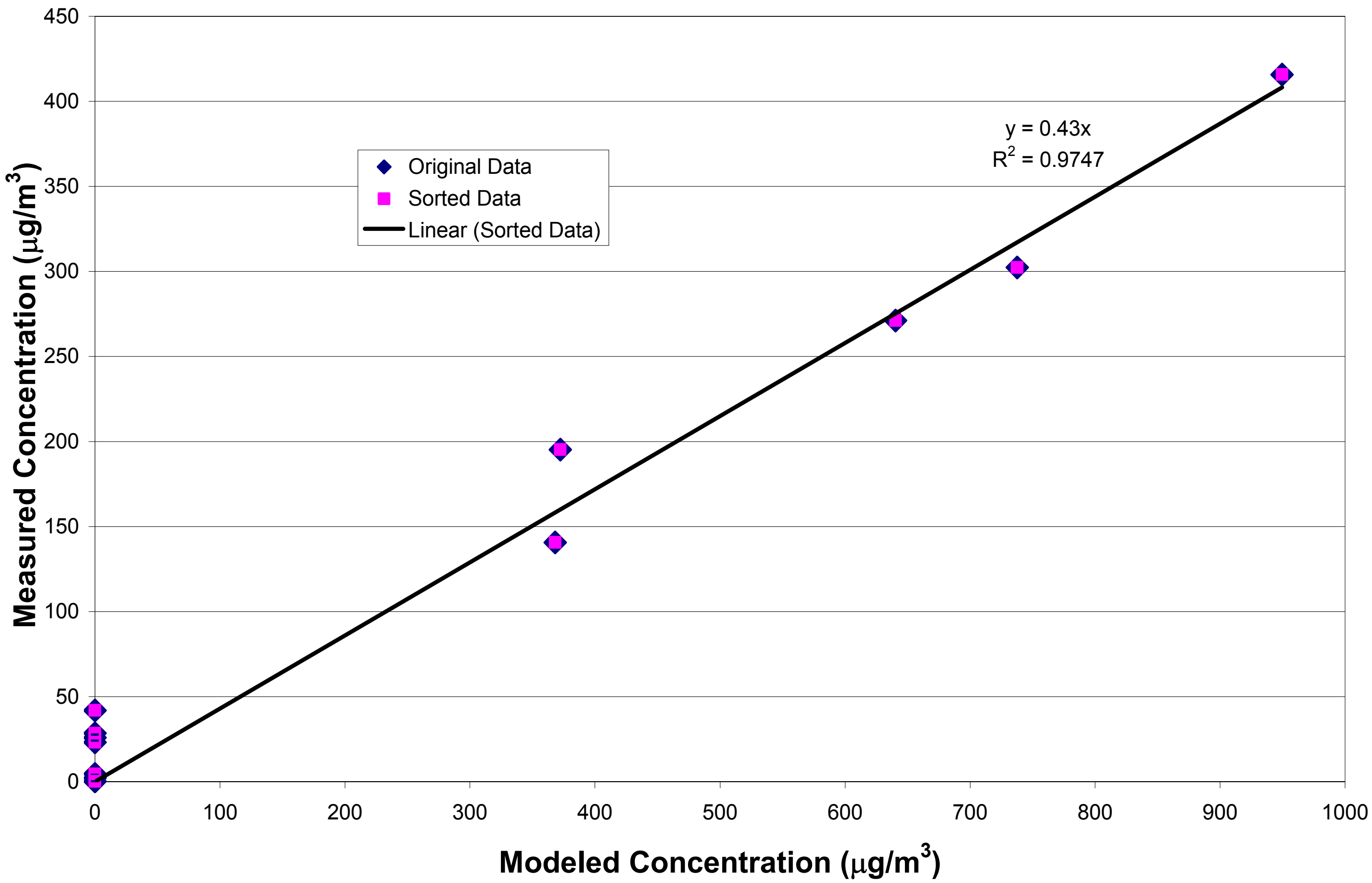


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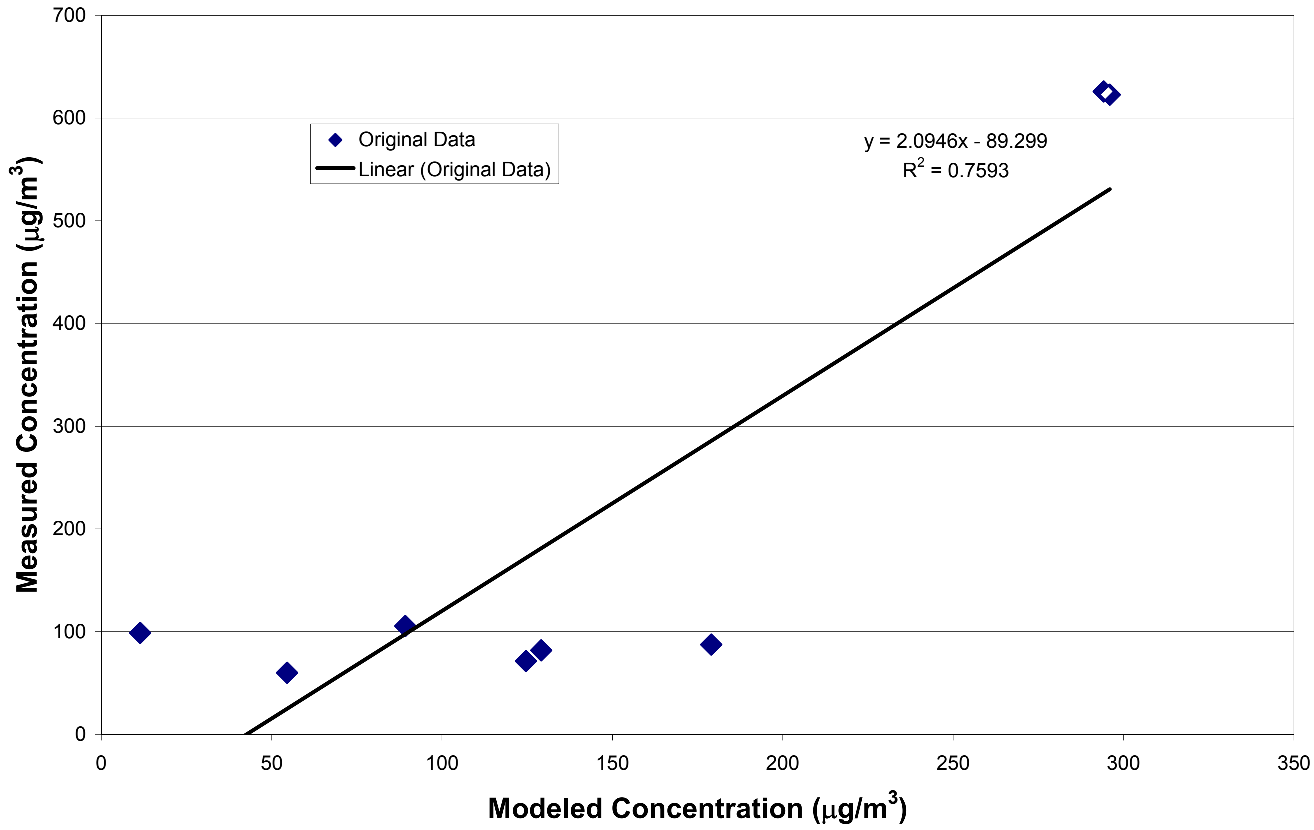
Figure 3.2. Comparison of Measured and Modeled Estimates for the First Period for the Watsonville Flat Fume Study



The CDPR method is complicated and sometimes requires subjective decisions, but CDPR has found that it is effective in their long experience analyzing the data from flux studies. A more straightforward approach would be to conduct the regression between the predicted and observed concentrations with the intercept constrained through zero. This technique would have the virtue of minimizing the sum of the squares of the residuals between the predicted concentrations from ISCST3 (after applying the adjusted flux rate) and the observed concentrations. The flux rate from this technique is arguably the "best fit" flux rate. Another technique would be to first normalize the observed and predicted concentrations by a logarithmic transformation, and then conduct a regression. The advantage of this method is that the raw concentrations may not be normally distributed as the values can range over several orders of magnitude, which would violate the assumption of normally implicit in linear regression. However, this method would minimize the sum of the squares of the residuals of the log-transformed values, not the actual values, and will place more emphasis on the lower values than with an un-transformed regression.

The CDPR method is often referred to as the indirect method, as a result of the back-calculation technique. There is also a direct method, which is sometimes called the aerodynamic method (Majewski et al., 1995). In the aerodynamic method, flux samples are collected using a mast located in the center of each field. Air and wind measurements are made at several heights above the surface, and the flux is calculated as the product of the concentration and wind gradients, adjusting for the atmospheric stability. CDPR compared the indirect and direct methods for methyl bromide and found reasonable agreement for a tarped field using a prior version of ISCST (Ross et al., 1996). For one of the Arvesta flux studies, both the indirect and direct methods were used with good agreement. The results of this comparison are discussed in Section 3.4.

3.2 Description of Flux Rate Studies

3.2.1 Introduction

Arvesta has conducted seven field studies of iodomethane applications since 2001 to estimate the flux of iodomethane under various field conditions and application scenarios. One of the most recent studies has not been completely analyzed yet, but will be before the SAP meeting. Each flux rate study was conducted by PTRL West, Inc. The general procedure for each of the studies was similar. In each study, 8-12 charcoal air samplers were set up on masts surrounding the application areas at a height of 1.5 meters. Generally, separate measurements were made during the daytime and the nighttime on each day. The separate daytime and nighttime measurements were made because the temperature difference between day and night may have some influence on the flux rate. These samplers were used to collect air samples from the time of application to a minimum of 10 days following the application. Using the results from these samplers, flux rates of iodomethane were back calculated using the CDPR methodology discussed above.

Table 3.1 provides a summary of all of the studies. There were three different application methods that were used, each representing a potential use for iodomethane that Arvesta is seeking a registration. The application methods include shallow shank broadcast flat fume (flat fume), raised bed, shallow shank injection (raised bed), and raised bed drip irrigation (drip irrigation). To date, Arvesta has conducted two studies for flat fume (Manteca and Watsonville), three studies for raised bed (Oxnard, Plant City, and Guadalupe), and two studies for drip irrigation (La Selva Beach and Camarillo). Other studies are planned contingent on the registration status of iodomethane. All of the methods use plastic tarps that cover the field after the application. The tarps limit the volatilization from the field, thus mitigating downwind air exposures and increasing the efficacy of the product by keeping it in the ground longer.

The field areas in the studies ranged from 0.4-2.48 acres. All of the studies (except the last two) were run with a target application rate of 235 lbs/acre, which was the original proposed maximum application rate for iodomethane. The current maximum proposed application rate is 175 lbs/acre. Therefore, for the buffer zone analysis, the flux estimates were adjusted to reflect the new rate as discussed below. The assumption of linearity between the application and flux rate makes physical sense and has been found to be a reasonable assumption by CDPR for methyl bromide. Most of the measurements started in the morning and finish in the morning or early afternoon, which is consistent with typical agricultural practice. However, the time required to set up the measurement equipment for the studies sometimes caused a later than planned start. This was the case for the studies at Oxnard and La Selva Beach, which both started at about noon and finished at 8pm (Oxnard) and 5:40pm (La Selva Beach). The late start and finish for these studies resulted in more of the emissions occurring in the evening and nighttime periods, which are less conducive to

Table 3.1 Summary of Field Studies

Study Name	**Manteca**	**Watsonville**	**Oxnard**	**Plant City**	**La Selva Beach**	**Camarillo**
Location	Manteca, CA	Watsonville, CA	Oxnard, CA	Plant City, FL	La Selva Beach, CA	Camarillo, CA
Date of Application	September 18, 2001	July 24, 2000	October 17, 2002	January 7, 2001	August 13, 2003	March 26, 2004
Time Application Started	9:05 AM	6:15 AM	12:08 PM	7:38 AM	12:00 PM	8:08 AM
Time Application Finished	11:45 AM	7:04 AM	7:58 PM	9:00 AM	5:41 PM	12:25 PM
Application Method	shallow shank broadcast flat fume	shallow shank broadcast flat fume	raised bed, shallow shank injection	raised bed, shallow shank injection	raised bed drip irrigation	raised bed drip irrigation
Shank Depth	11 inches	10 inches	6 inches	12 inches	NA	NA
Application Rate (target)	235 lbs/acre	235 lbs/acre	235 lbs/acre	235 lbs/acre	235 lbs/acre	175 lbs acre
Application Rate (actual)	241 lbs/acre	252 lbs/acre	243.7 lbs/acre	258 lbs/acre	234.3 lbs/acre	175.4 lbs acre
Area of Field	2.45 acres	0.40 acres	2.46 acres (1.727 treated acres)	0.40 acres (0.195 treated acres)	2.46 acres (1.725 treated acres)	2.48 acres (1.68 treated acres)
Soil Type	Sand	elder sandy loam	sandy loam w/ underlying loam & clay	Fort Meade loamy fine sand	Sandy loam	Sandy Loam
Number of Samplers	12	8	12	9	12	12
Number of Samples Collected	24 samples per mast	26 samples per mast	24 samples per mast	26 samples per mast	24 samples per mast	24 samples per mast

dispersion compared to the daytime. The impact of the application timing is discussed in the results section.

The remainder of this section discusses each of the field studies separately.

3.2.2 Manteca, California Flat Fume Study

The Manteca Study was conducted in September, 2001 on the property of Lassen Canyon Nursery in Manteca, California. Iodomethane was applied via a "tarped" shallow shank broadcast flat fume method to a 324 feet (98.8 meters) by 330 feet (100.6 meters) field at a target rate of 235 lbs/acre (actual rate of 241 lbs per treated acre). The application was made by tank injection through shanks at a depth of 11 inches. Simultaneous with application, a standard 1 mil plastic tarp was placed over the application plot. Thirty application passes were required to complete the application. The application was begun at 9:05 AM and completed at 11:45 AM. The tarps were cut five days after application and were removed seven days after application.

Twelve samplers were positioned near the field, with two samplers at approximately 30 feet from each side of the field and one sampler at approximately 141 feet from each corner of the field. The samplers were placed five feet above the ground. In addition five samplers were placed at varying heights on a mast at the center of the field for calculation of flux using the direct flux method. The iodomethane concentration measurements were made continuously for the 10 days following the application. Separate measurements were made during the daytime and the nighttime on each day. During the day of the application, measurements were made for three 4-hour periods in the daytime, and over a 12-hour period at night. For the remainder of the days, one daytime and one nighttime measurement (approximately 12 hours each) were made.

Meteorological measurements were made near the site, including wind speed, wind direction, with an averaging time of one minute.

3.2.3 Watsonville, California Flat Fume Study

The Watsonville Study was conducted in July, 2000 on the property of Plant Sciences in Watsonville, California. Iodomethane was applied via the "tarped" shallow shank broadcast flat fume method to a 200 feet (61.0 meters) by 88 feet (26.8 meters) field at a target rate of 235 lbs/acre (actual rate of 252 lbs per acre). The application was made by tank injection through shanks at a depth of 10 inches. Simultaneous with application, a standard 1 mil plastic tarp was placed over the application plot. A total of eight application passes were required to complete the application. The tarps were cut lengthwise five days after application and were removed seven days after application. Eight samplers were setup near the field, with two samplers on each side of the field ranging from 12 -30 feet from the field edge. The samplers were each placed 3 feet above the ground.

The iodomethane concentration measurements were made for 23 days following the application, but only every day for the first 10 days. For the first 10 days, daytime and nighttime measurements were made each day. After the first 10 days, the concentrations were significantly smaller. Therefore, the remaining daytime and nighttime measurements were made only on days 14 and 22. A monitor was also placed approximately 450 feet south of the southwest corner of the field. Because the monitor was in the upwind direction relative to the field, it was intended to measure background concentrations of iodomethane. The concentrations measured at this monitor were generally low (0 to 12.8 $\mu g/m^3$), indicating that background concentrations during the experiment were low. Therefore, this monitoring location was not included in the modeling analysis.

Meteorological measurements were made near the site, including wind speed and wind direction with an averaging time of one minute. These data were processed along with cloud cover data to generate hourly meteorological conditions for input into ISC.

3.2.4 Oxnard, California Raised Bed Study

The Oxnard Study was conducted in October, 2002 in Oxnard, California. Iodomethane was applied via a "tarped" raised bed shallow shank method to a 330 feet (100.6 meters) by 330 feet (100.6 meters) field at a target rate of 235 lbs/acre (actual rate of 244 lbs per treated acre). The application was made by tank injection through shanks at a depth of six inches to 48 inch wide raised beds. Simultaneous with application, a standard 1.5 mil plastic tarp was placed over the application plot. A total of 57 application passes were required to complete the application with the application beginning at 12:08 PM and concluding at 7:58 PM. The tarps were punched using a hole puncher mounted on a tractor five days after application.

Twelve samplers were positioned near the field, with two samplers at approximately 30 feet from each side of the field and one sampler at approximately 141 feet from each corner of the field. The samplers were placed five feet above the ground. The iodomethane concentration measurements were made continuously for the 10 days following the application. Separate measurements were made during the daytime and the nighttime on each day. During the day of the application, measurements were made for three 4-hour periods in the daytime, and over a 12-hour period at night. For the remainder of the days, one daytime and one nighttime measurement (approximately 12 hours each) were made.

Meteorological measurements were made near the site, including wind speed, wind direction, with an averaging time of one minute.

3.2.5 Plant City Florida Raised Bed Study

The Plant City Study was conducted in January, 2001 on the property of Plant Sciences in Plant City, Florida. Iodomethane was applied via a "tarped" raised bed application to a 200 feet (61.0 meters) by 86.25 feet (26.3 meters) field at a target rate of 235 lbs/acre (actual rate of 258 lbs per treated acre) to a tarped raised bed area. The application was made by tank injection through shanks at a depth of 12 inches to raised beds. Simultaneous with application, a standard 1.25 mil plastic tarp was placed over the application plot. The application was begun at 7:38 AM and completed at 9:00 AM. A total of 15 application passes were required to complete the application.

Eight samplers were positioned near the field, with two samplers placed 18-30 feet from each side of the field. The samplers were placed three feet above the ground. An additional sampler was positioned north of the field farther downwind.

The iodomethane concentration measurements were made continuously for the first 10 days, and again on day 14. Separate measurements were made during the daytime and the nighttime on each day. During the day of the application, measurements were made for three 4-hour periods in the daytime, and over a 12-hour period at night. For the remainder of the days, one daytime and one nighttime measurement (approximately 12 hours each) were made. A monitor was also placed approximately 212 feet north of the field. Because the monitor was in the upwind direction relative to the field, it was intended to measure background concentrations of iodomethane. However, for some periods, there were significant iodomethane concentrations measured at this monitor. Therefore, the data for this monitor were used in the modeling analysis.

Meteorological measurements were made near the site, including wind speed, wind direction, with an averaging time of one minute.

3.2.6 La Selva Beach, California Drip Irrigation Study

The La Selva Beach Study was conducted in August 2003, on the property of the Monterey Bay Academy in La Selva Beach, California. Iodomethane was applied via the drip irrigation method to a 330 feet (100.5 meters) by 330 feet (100.5 meters) field at a target rate of 235 lbs/acre (actual rate of 234 lbs per treated acre). The application was made by drip irrigation. Prior to application, the raised beds were covered with standard 1 mil plastic tarp. The application period lasted from 12:00 PM to 5:41 PM. The tarps were hole-punched five days after application and seven days after application a portion of the field was planted with strawberries.

Twelve samplers were setup around the field with two samplers placed 12-30 feet from each side of the field and one sampler between 113-141 ft from each corner. The samplers were placed five feet above the ground. The iodomethane concentration measurements were made for 10 days following the application. Generally, separate measurements were made during the daytime and the nighttime on each day.

Meteorological measurements were made near the site, including wind speed and wind direction with an averaging time of one minute.

3.2.7 Camarillo, California Drip Irrigation Study

The Camarillo Study was conducted in March 2004, on the property of California State University Channel Islands in Camarillo, California. The application was done on March 26, 2004. Iodomethane was applied via the tarped raised bed drip irrigation method to a 330 feet (100.5 meters) by 330 feet (100.5 meters) field at a target rate of 175 lbs/acre (actual rate of 175 lbs per treated acre). The application was made by drip irrigation. Prior to application, the raised beds were covered with standard 1 mil plastic tarp. The application period lasted from 8:08 AM to 12:25 PM. The tarps were hole punched five days after application and seven days after application a portion of the field was planted with strawberries.

Twelve samplers were setup around the field with two samplers placed 30 feet from each side of the field and one sampler 141 ft from each corner. The samplers were placed five feet above the ground. The iodomethane concentration measurements were made for 10 days following the application. Generally, separate measurements were made during the daytime and the nighttime on each day.

Meteorological measurements were made near the site, including wind speed and wind direction with an averaging time of one minute.

3.3 Estimates of Iodomethane Flux Rates

3.3.1 Introduction

In order to calculate flux rates for use in this modeling, the ISCST3 model was applied for each of the studies using study specific meteorological data, field dimensions, and sampler locations. All of the modeling runs assumed rural, flat terrain and used a nominal flux rate of 100 $\mu g/m^2/sec$. Consistent with the ISC guidance, the emission of iodomethane from the field was modeled as an area source (i.e., emissions are assumed to come uniformly from an area the size of the field). The model was programmed to calculate the average concentrations at each of the monitor locations for the specified periods. The periods selected were equivalent to the trapping intervals used in the field phase of each study.

Figures 3.3 through 3.5 display the flux rates for the six studies as a function of the mean time since application[5]. The figures are grouped by the three application methods. The peak flux rates always occurred on the first day, with a steady decline thereafter. The decline curves look relatively similar for the different pairs of studies. The fields were usually emitting negligible levels of iodomethane after a week. There is a distinct diurnal pattern to the flux rates, with higher flux rates apparent during the daytime compared to the nighttime. This phenomenon likely is due to the soil temperature, or possibly the increased permeability of the tarp during warmer periods.

[5] The mean time since application is defined by the midpoint of the trapping interval. For example, for a trapping interval over the first four hours since application, the mean time since application is 2 hours. This statistic allows the display of studies with different trapping intervals to be displayed on the same graph.

Figure 3.3. Estimated Flux Rate Versus Mean Time Since Application for Raised Bed Applications

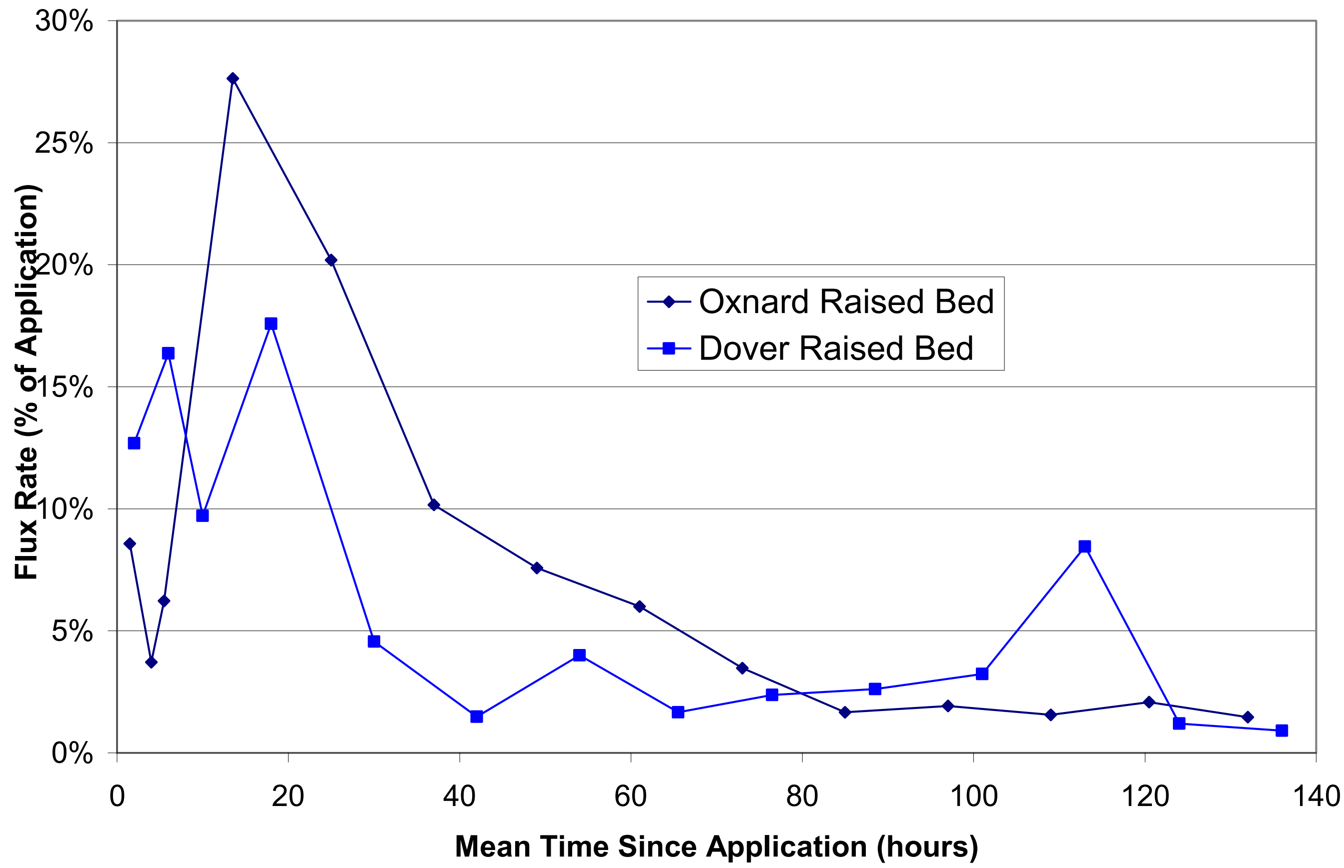


Figure 3.4. Estimated Flux Rate Versus Mean Time Since Application for Flat Fume Applications

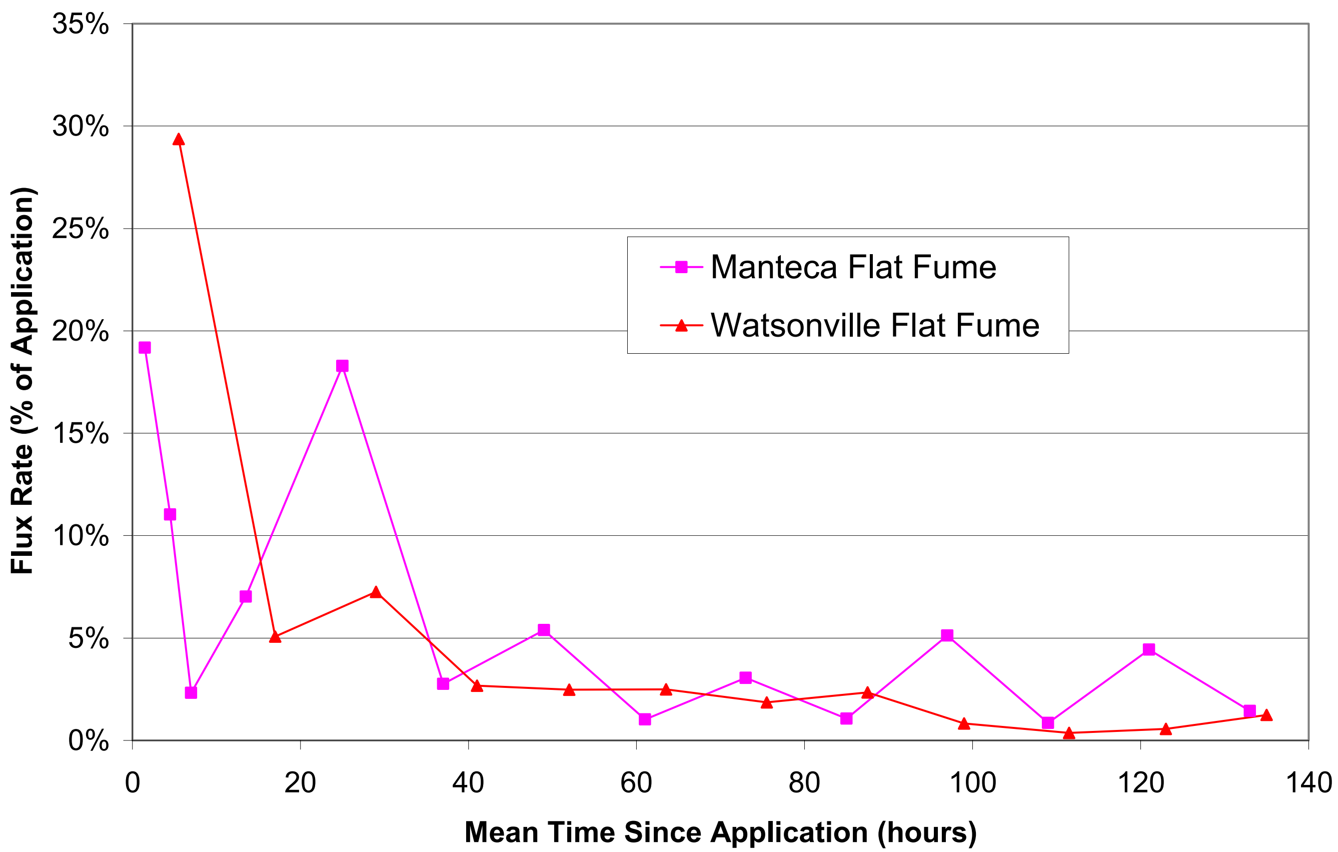
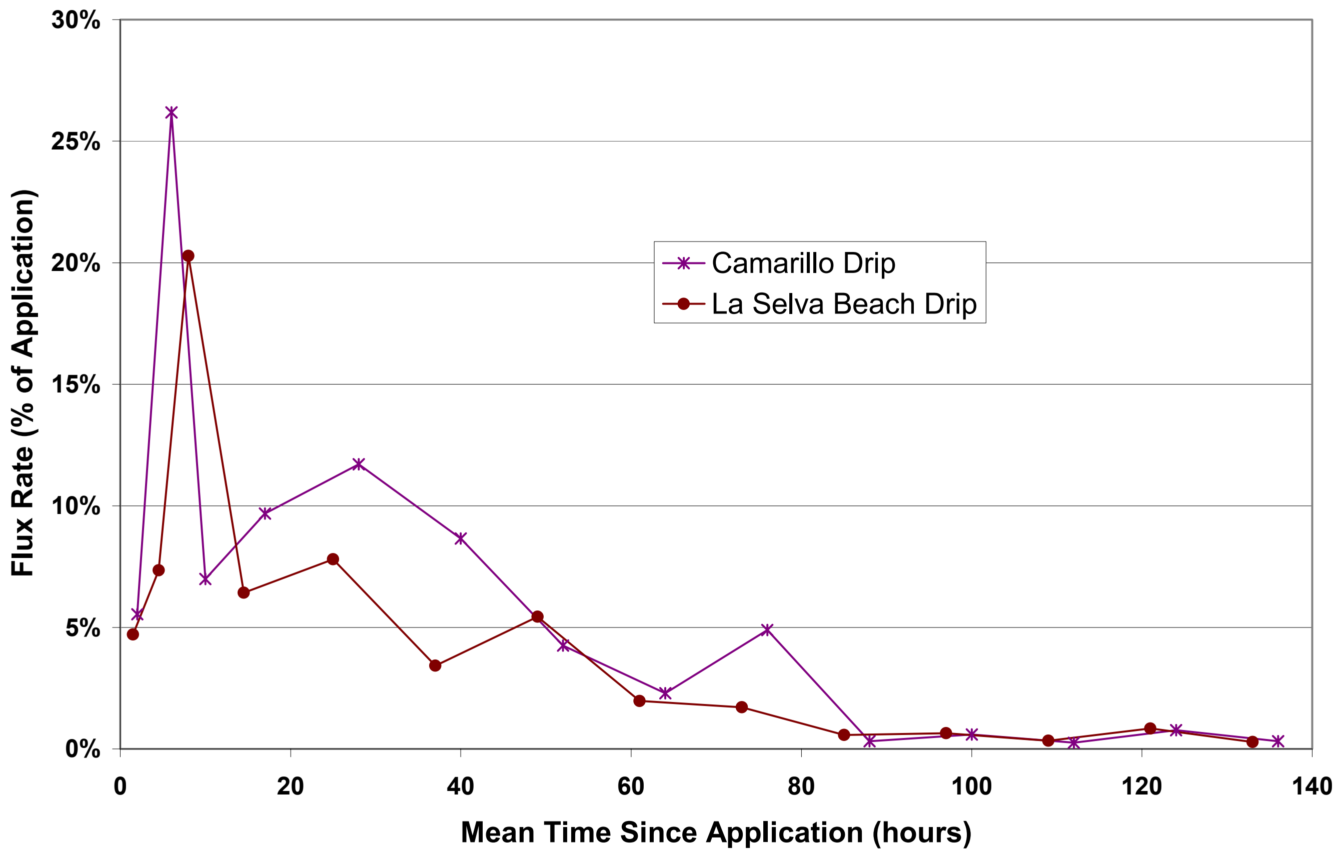


Figure 3.5. Estimated Flux Rate Versus Mean Time Since Application for Drip Irrigation Applications



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The flux rates for the first 24 hours were selected for use in the buffer zone modeling because it represents the peak exposure period for this acute exposure. This section presents a detailed discussion of the estimation of the flux rates for the first 24 hours of each study. The next section discusses the flux rates after the first day, and the impact of these levels on the risk assessment. All of the flux studies, except Camarillo, used a target application rate of 235 lbs/applied acre, which was the original, proposed maximum usage rate. The actual rate differed slightly from this target rate across the studies. The current maximum proposed usage rate is 175 lbs/applied acre. Each of the tables provides the estimated flux rate from the ISCST3 back-calculation (or the indirect method for Manteca) in μg/m^2/sec (the units used in ISCST3 model), which refers to the flux rate with the actual application rate (AR_{actual}). The following equation is used to adjust the flux rate to the current maximum usage rate, assuming a linear scaling of the flux rates and application rates:

$$Flux_{adj} = \frac{175\, lbs / acre}{AR_{actual}\ (lbs / acre)} \tag{3-4}$$

The tables also provide the mass of iodomethane that was emitted for each period in kilograms, which is calculated with the following formula:

$$Mass = Flux_{adj} * \left(\frac{3600 \sec}{1\, hr} \right) * T_{per}\,(hrs) * Size(m^2) * \left(\frac{1\, kg}{10^9\, \mu g} \right) \tag{3-5}$$

where T_{per} is the duration of the measurement period in hours and *Size* is the size of the field in m^2. Finally, the results from different flux studies can be contrasted by comparing the percentage of the application mass that was emitted over the first 24 hours, which is sometimes referred to as the emission ratio:

$$Emission\ \ Ratio = \frac{Mass\ Emitted\,(24\, hours)}{Mass\ Applied\,(24\, hours)} \tag{3-6}$$

For broadcast application, the applied acreage is the entire field, so expressing the application rate as applied acreage or total field acreage is equivalent. However, for raised bed and drip irrigation applications, the product is only applied to a portion of the field, and the maximum application rate refers to only the applied portion. Therefore, to estimate the mass applied, the application rate must be multiplied by the actual applied acreage (which is provided in Table 3.1), and is typically about 70% of the total field acreage.

In some cases, the second day of measurements started before 24 hours had elapsed from the start of the application (i.e., the first "day" of measurements was less than 24 hours). The duration of the measurements for the first period after the day of application was typically 12 hours. To have a flux rate estimate for the whole first 24 hours, the flux rate for the first period of the day after application was used for the remainder of the 24 hours.

3.3.2 Manteca and Watsonville Flat Fume Flux Estimates

The flux rate estimates for the two flat fume studies are shown in **Table 3.2** (Manteca) and **Table 3.3** (Watsonville). The coefficients of variances are included for the Watsonville study. CVs were not generated for the Manteca study since the indirect method was used, but the potential measurement error at Manteca is discussed in Section 3.5. The flux rates were fairly similar with 47% of the application being emitted in the first 24 hours for Manteca and 35% of the application being emitted in the first 24 hours for Watsonville. Due to the large initial sampling period (11 hours) for the Watsonville study, the large flux that occurs immediately after application is not as fully characterized as with the Manteca study.

Table 3.2. Estimated Flux Rates at Manteca for the First 24-Hours after Flat Fume Application

Period	Time Period	Hours	Estimated Flux Rate (μg/m²/sec)	Flux Rate Adjusted to 175 lbs/acre (μg/m²/sec)	Mass Emitted at 175 lbs/acre (kg)
1	12PM-3PM	3	481	349	37.4
2	3PM-6PM	3	276	200	21.5
3	6PM-8PM	2	87	63	4.5
4	8PM-7AM	11	48	35	13.7
5	7AM-12PM	5	115	84	14.9
			Total Mass Emitted (kg)		92.0
			Flux as a percentage of the application		47%
			24-Hour Average Flux Rate at 175 lbs/acre (μg/m²/sec)		107.4

Table 3.3. Estimated Flux Rates at Watsonville for the First 24-Hours after Flat Fume Application

Period	Time Period	Hours	Estimated Flux Rate from ISCST3 (μg/m²/sec)	CV (%)	Flux Rate Adjusted to 175 lbs/acre (μg/m²/sec)	Mass Emitted at 175 lbs/acre (kg)
1	8AM-7PM	11	209	22.9	145	9.3
2	7PM-7AM	12	33	7.4	23	1.6
3	7AM-8PM	1	47	4.6	33	0.2
				Total mass emitted (kg)		11.1
				Flux as a percentage of the application		35%
				24-Hour average flux rate at 175 lbs/acre (μg/m²/sec)		79.5

3.3.3 Oxnard and Plant City Raised Bed Flux Estimates

The flux rate estimates for the two raised bed studies are shown in **Table 3.4** (Oxnard) and **Table 3.5** (Plant City). The flux rates were very similar with 55% of the application being emitted in the first 24 hours for Oxnard and 57% of the application being emitted in the first 24 hours for Plant City.

Table 3.4. Estimated Flux Rates at Oxnard for the First 24-Hours after Raised Bed Application

Period	Time Period	Hours	Estimated Flux Rate from ISCST3 (μg/m^2/sec)	CV (%)	Flux Rate Adjusted to 175 lbs/acre (μg/m^2/sec)	Mass Emitted at 175 lbs/acre (kg)
1	12AM-3PM	3	535	4.4	109	11.7
2	3PM-5PM	2	179	5.6	71	5.1
3	5PM-8PM	3	111	13.8	79	8.5
4	8PM-7AM	11	134	8.1	96	37.8
5	7AM-12AM	5	90	8.2	64	11.5
				Total Mass Emitted (kg)		74.7
				Flux as a percentage of the application		55%
				24-Hour Average Flux Rate at 175 lbs/acre (μg/m^2/sec)		86.9

Table 3.5. Estimated Flux Rates at Plant City for the First 24-Hours after Raised Bed Application

Period	Time Period	Hours	Estimated Flux Rate from ISCST3 (µg/m^2/sec)	CV (%)	Flux Rate Adjusted to 175 lbs/acre (µg/m^2/sec)	Mass Emitted at 175 lbs/acre (kg)
1	9AM-1PM	4	126	10.6	85	2.0
2	1PM-5PM	4	163	24.7	110	2.6
3	5PM-9PM	4	96	27.2	65	1.5
4	9PM-9AM	12	58	21.7	39	2.8
				Total Mass Emitted (kg)		8.8
				Flux as a percentage of the application		57%
				24-Hour Average Flux Rate at 175 lbs/acre (µg/m^2/sec)		63.2

3.3.4 La Selva Beach and Camarillo Raised Bed Flux Estimates

The flux rate estimates for the two raised bed studies are shown in **Table 3.6** (La Selva Beach) and **Table 3.7** (Camarillo). The flux rates were very similar with 42% of the application being emitted in the first 24 hours for La Selva Beach and 50% of the application being emitted in the first 24 hours for Camarillo.

3.3.5 Summary

Table 3.8 summarizes the flux rates for the first 24 hours after application. The hour that the application started is shaded, so the values for hours before the start time actually refer to the hours on the following evening.

Table 3.6. Estimated Flux Rates at La Selva Beach for the First 24-Hours after Drip Irrigation Application

Period	Time Period	Hours	Estimated Flux Rate from ISCST3 ($\mu g/m^2/sec$)	CV (%)	Flux Rate Adjusted to 175 lbs/acre ($\mu g/m^2/sec$)	Mass Emitted at 175 lbs/acre (kg)
1	12AM-3PM	3	79	10.1	59	6.4
2	3PM-6PM	3	124	21.2	92	9.9
3	6PM-10PM	4	256	5.1	191	27.4
4	10PM-7AM	9	36	6.8	27	8.7
5	7AM-12PM	5	33	17.6	25	4.4
				Total Mass Emitted (kg)		56.8
				Flux as a percentage of the application		42%
				24-Hour Average Flux Rate at 175 lbs/acre ($\mu g/m^2/sec$)		66.0

Table 3.7. Estimated Flux Rates at Camarillo for the First 24-Hours after Drip Irrigation Application

Period	Time Period	Hours	Estimated Flux Rate ($\mu g/m^2/sec$)	CV (%)	Flux Rate Adjusted to 175 lbs/acre ($\mu g/m^2/sec$)	Mass Emitted at 175 lbs/acre (kg)
1	8AM-12PM	4	51	3.3	51	7.4
2	12PM-4PM	4	242	7.0	242	34.9
3	4PM-8PM	4	65	20.4	65	9.3
4	8PM-6AM	10	36	8.8	36	12.9
5	6AM-6PM	2	36	24.4	36	2.6
				Total Mass Emitted (kg)		67.1
				Flux as a percentage of the application		50%
				24-Hour Average Flux Rate at 175 lbs/acre ($\mu g/m^2/sec$)		77.4

Table 3.8. Flux Rate Estimates for the First 24-Hours after Application

Time of Day	Estimated Flux Rates for Modeling Adjusted to 175 lbs/acre ($\mu g/m^2/sec$)					
	Manteca	Watsonville	Oxnard	Plant City	La Selva Beach	Camarillo
12:00 AM	35	23	96	39	27	36
1:00 AM	35	23	96	39	27	36
2:00 AM	35	23	96	39	27	36
3:00 AM	35	23	96	39	27	36
4:00 AM	35	23	96	39	27	36
5:00 AM	35	23	96	39	27	36
6:00 AM	35	23	96	39	27	36
7:00 AM	84	33	64	39	25	36
8:00 AM	84	145	64	39	25	51
9:00 AM	84	145	64	85	25	51
10:00 AM	84	145	64	85	25	51
11:00 AM	84	145	64	85	25	51
12:00 PM	349	145	109	85	59	242
1:00 PM	349	145	109	110	59	242
2:00 PM	349	145	109	110	59	242
3:00 PM	200	145	71	110	92	242
4:00 PM	200	145	71	110	92	65
5:00 PM	200	145	79	65	92	65
6:00 PM	63	145	79	65	191	65
7:00 PM	63	23	79	65	191	65
8:00 PM	35	23	96	65	191	36
9:00 PM	35	23	96	39	191	36
10:00 PM	35	23	96	39	27	36
11:00 PM	35	23	96	39	27	36

Note: Measurements started on hour that is shaded. The flux estimates before these hours are for the day after.

3.4 Emissions on the Second Day after Application

As with methyl bromide, the bystander risk assessment for iodomethane will focus on the emissions over the first 24 hours, which produce the peak exposures. There are still emissions after the first day, so it is useful to compare the emissions on the day of application with the emission for the second 24-hours. **Table 3.9** summarizes the percentage of the application that was emitted for the first and second 24-hours for each of the studies, and also provides the ratio of the first and second 24-hour emissions. The ratio of the first and second-day emissions ranged from 2.2 (Oxnard) to 9.5 (Plant City). For Plant City, the estimate of emissions for the second day is biased low due to rainfall. For Oxnard, the high emissions on the second day may relate to the late timing of the application. The results section (Section 5) will provide some modeling analysis to address potential exposures and risk on the day after the application.

Table 3.9. Emissions Over the First and Second 24-Hour Periods after the Application

Study	Flux as Percentage of the Application Rate		Ratio of First and Second 24-Hours
	First 24-Hours	Second 24-Hours	
Manteca Flat Fume	47%	16%	2.9
Watsonville Flat Fume	35%	10%	3.5
Oxnard Raised Bed	55%	25%	2.2
Plant City Raised Bed	57%	6%[a]	9.5
La Selva Beach Drip Irrigation	42%	10%	4.2
Camarillo Drip Irrigation	50%	19%	2.6

[a] This value is biased low because of rain during the second and third days after the application, which washed out the iodomethane preventing an accurate back-calculation.

3.5 Comparison of Direct and Indirect Flux Estimates for Manteca

As mentioned previously, the Manteca study was set up so that flux estimates could be calculated using both the direct and indirect flux methods. The direct flux method involves the placement of air monitors at varying heights in the center of the field. The flux estimates for Manteca using both methods were similar as seen in **Table 3.10**. The agreement between the two methods was very good. While there was some variation across the different periods, the overall estimate of the amount emitted over 24-hours was very similar (47% for the direct method and 50% for the indirect method). Also, there was no apparent bias between the methods, with either the direct or indirect method giving a higher estimate for any given period. The similarity of the 24-hour estimates may the result of a regression to the mean with the measurement errors across the different periods averaging out over time.

Table 3.10. Comparison of Flux Rates for Manteca using Direct and Indirect Calculation

Period	Time Period	Hours	Flux Rate Adjusted to 175 lbs/acre (μg/m^2/sec)		Mass Emitted at 175 lbs/acre (kg)	
			Direct Method	Indirect Method	Direct Method	Indirect Method
1	12-3pm	3	349	310	37.4	33.1
2	3pm-6pm	3	200	144	21.5	15.4
3	6pm-8pm	2	63	144	4.5	10.3
4	8pm-7am	11	35	76	13.7	29.8
5	7am-2pm	5	84	44	14.9	7.8
			Total Mass Emitted (kg)		92.0	96.5
			Flux as a percentage of the application		47%	50%
			24-Hour Average Flux Rate at 175 lbs/acre (μg/m^2/sec)		107.4	112.6

4.0 DESCRIPTION OF AVAILABLE METEOROLOGICAL DATA

4.1 Available Sources of Meteorological Data

For a given flux rate from a field, the predominant influence on the resulting downwind concentrations is the meteorological conditions of the atmosphere. The key meteorological inputs to the ISCST3 model are the wind speed, wind direction, and atmospheric stability class. As described above, the atmospheric stability is a measure of the vertical mixing of the atmosphere. The mixing height is also an input into the model, but for estimates of concentrations very close to a ground-level source, the mixing height has little or no impact. Also, the ambient temperature is an input to the model, but it has no affect on the concentration estimates for this circumstance. The ISCST3 model is run on an hourly basis, so hourly meteorological data are required.

The focus of the analysis is on the potential use areas for iodomethane in Florida and California. However, the model is a general tool that can be used with data from any meteorological station, as long as it can be put into ISCST3 format. The meteorological conditions in these two states represent a broad range of situations, including inland and coastal sites, and should encompass many of the meteorological situations that may be encountered in states with less usage. We identified four potential data sources for meteorological data in the growing regions of California and Florida:

- *National Weather Service (NWS)* data that are available on EPA's dispersion modeling website[6], and that has been routinely used for dispersion modeling over the years. These data were collected by trained observers. The stations are mostly at large airports.

- *Automated Surface Observing System (ASOS)* data that are collected throughout the country by the Federal Aviation Administration (FAA) from automated collection systems at airports (both large and small). ASOS replaces the observer-collected systems.

- *California Irrigation Management Information System (CIMIS)* data that are collected by the California Department of Water Resources, and are used to

[6] See http://www.epa.gov/scram001/tt24.htm

support agricultural practices. CIMIS also uses an automated collection system.

- *Florida Automated Weather Network (FAWN)* data are collected by a consortium of groups in Florida, and is used to support agricultural practices. FAWN is an automated collection system.

Data were obtained from each of these sources for detailed analysis.

4.2 Advantages and Disadvantages of Each Data Source

Table 4.1 lists advantages and disadvantages of each of the data sources. The NWS data are a preferred source for dispersion modeling. These data have been widely used by EPA for dispersion modeling applications over the years, and are available for download from EPA's air dispersion modeling website. The NWS data are observer-collected and have been reviewed by a trained meteorologist for data quality. However, most of the NWS stations are at large airports in urban areas, and may not be representative of the meteorology in the growing regions. Therefore, other sources of data were also explored to assure that the data that is used in the buffer zone analysis is representative of the areas where actual applications will occur.

Table 4.1. Advantages and Disadvantages of Different Sources of Meteorological Data

Data Source	Advantages	Disadvantages
NWS	• Widely used data historically • High quality control – data reviewed by a meteorologist	• Few stations, most not in growing regions
ASOS	• Large number of stations, many in growing areas	• Only automated quality control
CIMIS	• Large number of stations in growing areas of California	• Only automated quality control • Collected at 2 meters, a non-standard height
FAWN	• Stations in the key growing areas of Florida	• Very little quality control

The ASOS network is a relatively recent addition, with operations beginning in the early 1990s. ASOS is an automated network with stations at many large and small airports. Therefore, the data are available in many growing regions of California, and in some of Florida. There is a limited quality control of data using an automated system that flags potential problems. A more extensive quality control is done to develop daily summaries of the data; however, the changes to the hourly data are not available for download.

The CIMIS stations are an agricultural network in California, mostly used to assist in irrigation planning. The stations are located in the key growing areas. One of the disadvantages of the CIMIS data is that the wind speed and wind direction sensors are positioned at a 2 meter height. The standard height that is recommended for dispersion modeling is 10 meters (EPA, 2000). At low heights, the wind speed is generally lower due to surface friction. Additionally, the wind direction can be more variable and random due to turbulent eddies caused by the ground friction. Higher measurement heights are generally used to lessen the effects from the surface, and the data from these heights are more representative of the surroundings. The ASOS and FAWN networks are collected at 10 meters, and the NWS data ranges from 6-10 meters.

The FAWN network is also an agricultural network, but in Florida. The stations are located in key growing regions. The major disadvantage of the FAWN network is the lack of quality control. In an email, Lawrence Treadway, a coordinator for the FAWN project, described the quality control of the FAWN data as “very rudimentary” (Personal communication with Lawrence Treadway, April 30, 2004).

4.3 Processing Methods for Each Data Source

The raw meteorological data from each of the data sources needs to be processed into ISCST3-formatted meteorological input files. The most important part of this processing step is the estimation of the atmospheric stability. There are several methods for estimating atmospheric stability classes (EPA, 2000), and the ideal method may be different for different sources of data. This subsection discusses the methodologies that were used for each data source.

4.3.1 *National Weather Service*

The NWS data are available in a format that is compatible with EPA's PCRAMMET program (EPA, 1999b), which was developed to prepare ISC-formatted meteorological data files. PCRAMMET uses the Turner method to estimate the atmospheric stability class. The Turner method is an implementation of the Pasquill stability class system summarized in Table 2.1. The Turner method is the most common method that is used to estimate atmospheric stability classes, and the estimation of the classes is dependent upon the wind speed, solar angle (daytime), cloud cover, and cloud ceiling height.

PCRAMMET also estimates atmospheric mixing heights, which are also an input to the ISCST3 model, based on sounding data that are also available on the EPA dispersion modeling website. However, in some instances, PCRAMMET estimates very low, unrealistic mixing heights (<10 meters). In modeling analysis, mixing heights below 10 meters are typically converted to 10 meters to prevent unrealistic concentrations. There is no formal EPA guidance on this matter, but the treatment of low mixing heights is normally worked out with EPA regional modelers when developing a regulatory dispersion modeling analysis[7]. As will be discussed later, the mixing height had only a very small effect on the buffer zone estimates. For the remaining meteorological data sources, the mixing height was set to a nominal value of 300 meters (or 320 meters for CIMIS), since it would require additional processing to add mixing heights for these data sources.

4.3.2 *Automated Surface Observing System*

The ASOS data were downloaded from the National Climatic Data Center (NCDC) website (http://www.ncdc.noaa.gov/oa/ncdc.html). The last five complete years were obtained (1999-2003) for each station. The data were first processed in a Microsoft Access® database to develop raw text files with the hourly data that were then read into a FORTRAN program to calculate the atmospheric stability class and output the data in the proper ISC format. As with the NWS data, the Turner method was used to estimate the stability classes. The ASOS data are not in a format that can easily be inputted into PCRAMMET. However, the PCRAMMET FORTRAN subroutines that are used to calculate the solar angle (SUN) and stability class (STABIT) were copied

[7] Personal communication with Dennis Atkinson at U.S. EPA OAQPS, EPA contact person for ISC, March 8, 2004.

from the PCRAMMET source code and incorporated into the program to process the ASOS data, to ensure that the calculation accurately reproduced EPA's methodology.

One of the required inputs for estimating the stability class is the cloud cover. ASOS uses an automated system to estimate cloud cover and ceiling height (and all other parameters), as opposed to the human observer systems used for the NWS data. For any given hourly measurement, the system may record up to three separate cloud cover and ceiling height measurements. The cloud cover measurements are recorded as one of four categories: (1) clear (0.0), (2) scattered (0.3), (3) broken (0.7), and (4) overcast (1.0). These categories must be converted into a fractional cloud cover to estimate stability, which are shown in parentheses above in accordance with an EPA analysis of the utility of ASOS data for dispersion modeling (EPA, 1997). Also, a single cloud cover and ceiling height measurement is required for each hour, but for some hours there are multiple measurements. Consistent with EPA's ASOS analysis, the single measurement that yields the largest cloud cover, and the single measurement that yields the lowest ceiling height was used.

4.3.3 California Irrigation Management Information System

The CIMIS data files were prepared by CDPR, and the process used to prepare the files is provided in CDPR's report on its methyl bromide buffer zones validation analysis (CDPR, 2001). The CIMIS stations do not include measurements of cloud cover and ceiling height, so the Turner method is not an ideal method for estimating the stability classes with the CIMIS data. However, the CIMIS data includes estimates of the standard deviation of the wind direction, which can be used with the σ_θ method (see Table 6-9 of EPA, 2000) to estimate stability. CDPR used the EPA recommended factors to adjust the σ_θ method for data collected at other than 10 meters (2 meters for CIMIS). However, the wind speed and wind direction were not adjusted for the lower measurement height.

4.3.4 Florida Automated Weather Network

The FAWN data were downloaded from the FAWN website (http://fawn.ifas.ufl.edu/). FAWN does not include concurrent cloud cover and ceiling height measurements, so Turner's method cannot be used to estimate stability classes. Also, sub-hourly measurements are made at the FAWN stations, but only every 15 minutes, which is insufficient for the σ_θ method. However, the FAWN stations include hourly measurements of solar radiation flux, and air temperature at 2 and 10 meters. Therefore, the solar radiation/delta-T (or SRDT) method can be used to estimate the stability classes (see EPA, 2000, p. 6-15). The SRDT methodology estimates the atmospheric stability classes based on the solar radiation flux, and the vertical temperature gradient between temperature measurements at 2 and 10 meters.

There were a number of clearly erroneous data points in the FAWN data. For example, there were several times when the wind speeds were greater than 100 mph, and the preceding and succeeding hours were normal. When this occurred, the wind speed was identified as missing, and a new value interpolated. Similarly, there were some values for the solar radiation and wind direction that were beyond reasonable or physically possible ranges, and were interpolated instead.

4.4 Selection of meteorological stations for PERFUM analysis

Among the four sources of data, there are a plethora of stations to choose from for the buffer zone analysis. However, the runtime of the PERFUM model is not trivial (about an hour to run a set of five runs of each field size for a set of flux data and meteorological station). Additionally, except for NWS, there is a significant effort required to process the meteorological data into the ISC format. Therefore, it is impractical to run the modeling system for all of the stations that are available. Instead, this section presents modeling results for 15 stations in California and Florida, and a selection of four stations that are representative of all of the stations.

Four stations were chosen for analysis from the NWS, CIMIS, and ASOS networks. For the FAWN network, three stations were chosen for analysis. The stations were chosen that most represent agricultural growing regions. The list of stations is summarized in **Table 4.2,** including the years of data that were used. **Figure 4.1** displays the locations in California, and **Figure 4.2** displays the locations in Florida. Consistent with EPA's dispersion modeling guidelines, five years of data were used from each station (EPA, 2003a). For the ASOS and FAWN stations, the last complete years available (1999-2003) were used. For NWS, the last five complete years of data available on EPA's dispersion modeling website were used, except for Santa Barbara where only three years of data are available. The periods for the CIMIS stations were chosen by CDPR.

There was missing data at many of the stations. As discussed later, there are procedures for estimating missing data. However, these procedures are onerous. Therefore, for the purposes of this preliminary analysis, only days with complete data were used in the analysis.

Figure 4.1. Locations of Meteorological Stations in California

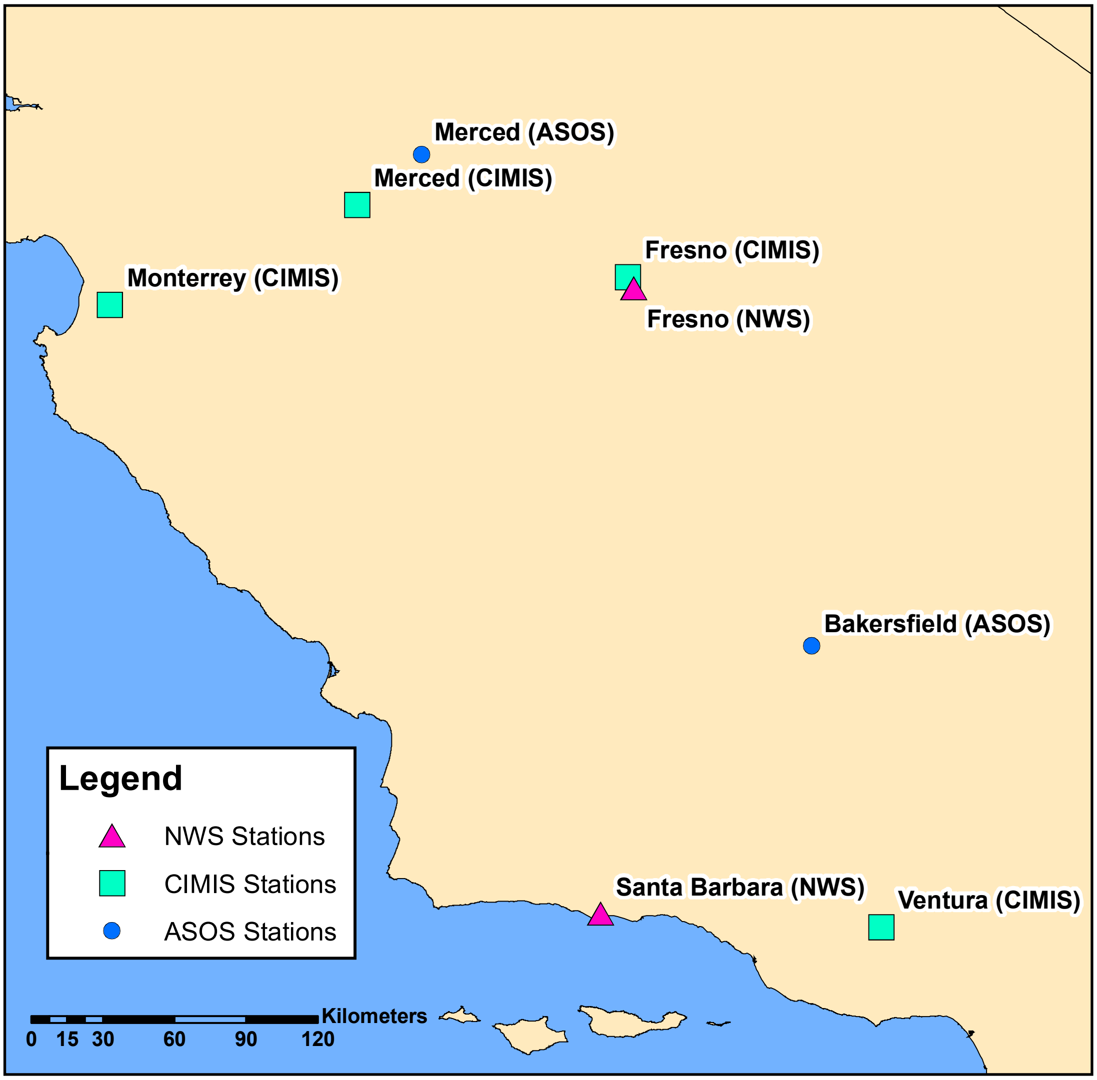


Figure 4.2. Locations of Meteorological Stations in Florida

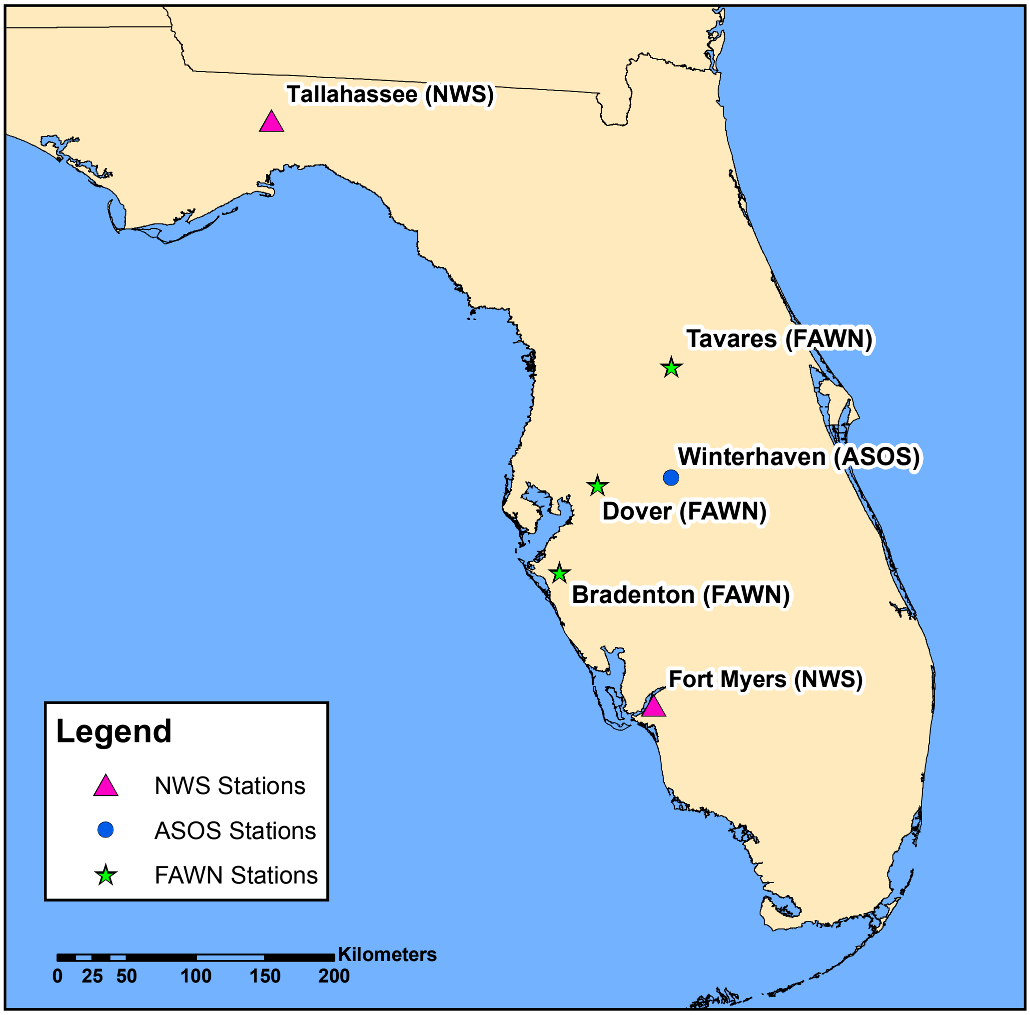


Table 4.2. Meteorological stations used in preliminary dispersion modeling analysis (time period for data in parentheses)

ASOS	CIMIS	FAWN	NWS
Bakersfield, CA (1999-2003)	Fresno, CA (1984-1988)	Bradenton, FL (1999-2003)	Fort Myers, FL (1988-1992)
Merced, CA (1999-2003)	Merced, CA (1993-1997)	Dover, FL (1999-2003)	Fresno, CA (1988-1992)
Watsonville, CA (1999-2003)	Monterrey, CA (1995-1999)	Tavares, FL (1999-2003)	Santa Barbara, CA (1984-1986)
Winterhaven, FL (1999-2003)	Ventura, CA (1995-1999)		Tallahassee, FL (1988-1992)

The buffer zone model was run with each of the ASOS, FAWN, CIMIS, and NWS meteorological files, with both the Oxnard and Manteca flux data (adjusted to a 175 lbs/applied acre application rate). Between the four data sources, there were 15 meteorological stations. A 5 acre field was assumed for all of these scenarios. The purpose of these model runs was to determine a representative set of meteorological stations to base the final analysis.

Table 4.3 summarizes the buffer zone estimates for the each of the 15 meteorological stations for both the Oxnard and Manteca flux data[8]. For the Oxnard flux data, the average buffer zone for the 15 meteorological files was 715 feet, and the range was 518 feet (NWS-Santa Barbara) to 872 feet (FAWN-Tavares). The standard deviation was 87 feet, giving a small coefficient of variation (CV) of 12%. For the Manteca flux data, the average buffer zone for the 15 meteorological files was 623 feet, and the range was 544 feet (ASOS-Bakersfield) to 748 feet (FAWN-Tavares). The standard deviation was 61 feet, giving a small CV of 10%. These data show that there is some variability among stations, but it does not approach an order of magnitude difference.

[8] These results differ from the final results presented in Section 5 because missing data was replaced prior to the final analysis, and a few minor changes in the model were made between the performance of the analysis in this Section and Section 5.

For the Oxnard flux data, the buffer zones were lowest using the NWS stations (average of 640 feet), followed by the ASOS stations (697 feet), and the CIMIS stations (725 feet). The results with the FAWN stations were significantly higher (829 feet). For the Manteca flux data, the buffer zones were very similar with the NWS stations (596 feet), ASOS stations (595 feet), and the CIMIS stations (602 feet). With the FAWN stations, the buffer zones were significantly higher (726 feet).

There are too few stations in this analysis to draw any broad conclusions, but a few observations are made. First, there was not a significant difference between the NWS, ASOS, and CIMIS stations. The overall results for these stations were relatively similar. Furthermore, the results were similar for comparisons between stations in the same area (Fresno between CIMIS and NWS, and Merced between CIMIS and ASOS). Also, there was not a discernable pattern between the coastal and inland stations, or stations that are clearly in agricultural regions compared to more urban stations (e.g., Fort Myers or Tallahassee). It is clear that the FAWN stations resulted in the largest buffer zone estimates.

Table 4.3. Estimated Buffer Zones with Different Meteorological Stations for a 5 Acre Field

Source	Location	Buffer Zones (feet)	
		Oxnard (Raised Bed)	Manteca (Flat Fume)
ASOS	Bakersfield	659	544
	Merced	741	633
	Watsonville	646	594
	Winterhaven	741	610
CIMIS	Fresno	754	571
	Merced	741	604
	Monterrey	725	581
	Ventura	679	653
FAWN	Bradenton	869	705
	Dover	745	725
	Tavares	872	748
NWS	Fort Myers	692	581
	Fresno	702	620
	Santa Barbara	518	554
	Tallahassee	646	630
Average		715	623
Standard Deviation		87	61
Minimum		518	544
Maximum		872	748

Table 4.4 summarizes the average buffer zones and data completeness for each of the stations. The data are also sorted by the average buffer zone, and divided into quartiles. The last quartile has only three stations because there is a total of 15 stations (but 16 would be needed to have four stations in each quartile). For the final buffer zone determination, we chose a representative station from each quartile. The shaded stations in Table 4.4 are the stations we plan to use for the analysis in this report, which include:

1) Bakersfield, California/ASOS

2) Tallahassee, Florida/NWS
3) Ventura, California/CIMIS
4) Bradenton, Florida/FAWN

These stations represent coastal and inland stations in California and Florida, and one station from each of the four data sources. For these four stations, the average buffer zone using the Oxnard flux rates was 713 feet, compared to an overall average of 715 feet for all of the stations. Therefore, the average of the four stations is 0.25% less than the overall average. The average buffer zone for the four stations using the Manteca flux rates was 633 feet, compared to an overall average of 623 feet. Therefore, the average of the four stations is 1.6% higher than the overall average. These comparisons show that the four chosen stations are representative of the 15 stations.

The stations chosen also have relatively complete data. EPA's standard dispersion modeling methods require 100% complete data, and EPA has developed a methodology to estimate missing data when necessary (EPA, 1992). The missing data technique was already applied to the NWS data by EPA, so these data are 100% complete. CDPR replaced most of the missing data in the CIMIS files, resulting in 98.9% completeness for the Ventura station. CDPR determined that data for the remaining 1.1% of the days could not be reasonably inferred. Therefore, the Ventura data will be used as provided by CDPR. Although this meteorological file doesn't strictly meet EPA's criterion of 100% data completeness, the small amount of missing data (1.1%) is unlikely to significantly impact the results of the analysis. Therefore, the data were used as provided by CDPR. For the ASOS-Bakersfield and the FAWN-Bradenton stations, EPA's missing data methods were applied to estimate as much of the missing data as possible (see Section 4.6).

Table 4.4. Average Buffer Zones and Data Completeness for Meteorological Stations

Quartile	Data Source	Station Location	Buffer Zones (feet)			Data Completeness[a]
			Oxnard Flux	Manteca Flux	Average	
1	NWS	Santa Barbara	518	554	536	100
	ASOS	Bakersfield	659	544	602	96.9
	ASOS	Watsonville	646	594	620	88.3
	NWS	Fort Myers	692	581	637	100
2	NWS	Tallahassee	646	630	638	100
	CIMIS	Monterrey	725	581	653	99.4
	NWS	Fresno	702	620	661	100
	CIMIS	Fresno	754	571	663	95.1
3	CIMIS	Ventura	679	653	666	98.9
	CIMIS	Merced	741	604	673	98.9
	ASOS	Winterhaven	741	610	676	90.3
	ASOS	Merced	741	633	687	85.5
4	FAWN	Dover	745	725	735	83.4
	FAWN	Bradenton	869	705	787	91.1
	FAWN	Tavares	872	748	810	88.7

[a] Completeness is defined as complete days, meaning all 24 hours must be available for a day to be considered complete.

4.5 Impact of the mixing height on the estimated buffer zones

For the National Weather Service meteorological data, the mixing height was estimated from upper-air data using the PCRAMMET program. However, for the other data sources, it was not as simple to develop mixing heights. It was hypothesized that the mixing height was not a important factor in these calculations because the downwind concentrations of interest are relatively close to the source. Therefore, the plume has a limited time to ascend to a height where the mixing height begins to effect the dispersion. From this hypothesis, nominal mixing heights of 300 meters (or 320 meters for the CIMIS data) were used to construct the data files.

Table 4.5 summarizes a sensitivity analysis for the mixing height using the Tallahassee NWS data and the flux data from Manteca. The model was applied for each of the five field sizes using the PCRAMMET-derived input file for Tallahassee, and an alternative input file where all the mixing heights were changed to 300 meters. The estimate of the buffer zone (using the 95th percentile) was not affected for 1, 5, and 10 acre fields. For the 20 and 40 acre fields, there was only a very small difference (<0.2%). Therefore, it is concluded that the mixing height is not an important parameter for these calculations, and the use of nominal mixing heights only negligibly impacts the calculations.

Table 4.5. Buffer Zone Estimates for Manteca Flux Data with Tallahassee Meteorological Data With Different Mixing Heights

Field Size (Acres)	Buffer Zone Estimate at 95th Percentile (feet)	
	PCRAMMET Mixing Heights	All Mixing Heights Assigned to 300 meters
1	230	230
5	636	636
10	974	974
20	1490	1489
40	2293	2289

4.6 Characterization of meteorological data for buffer zone analysis

This subsection provides a characterization of the meteorological variables at the four stations chosen for the buffer zone analysis, including the daily average wind speed, the wind direction, and the stability class.

Figure 4.3 provides a graph of the distribution of daily average wind speeds at the four sites. The y-axis shows the percentile of the distribution. For example, the 50th percentile for Bakersfield is 2.61 m/sec, which means that the daily average wind speed is less than or equal to 2.61 m/sec on 50% of the days, and greater than or equal to on 50% of the days. The figure shows that the daily average wind speed distributions for Ventura, Tallahassee, and Bakersfield are relatively similar. The distribution for Bradenton shows lower wind speeds than the other three sites, which may partly explain why the Bradenton buffer estimates were the highest.

Figure 4.4 presents the frequency distribution of the stability classes at each of the stations. The most frequent stability classes are D and F, except at Ventura where stability class C is more frequent than D. The atmosphere was generally the most stable at Bakersfield with 75% of the stability classes being D or above. For the remainder of the stations, the percentage of stability classes at D or above was 62% (Ventura), 66% (Bradenton), and 68% (Tallahassee).

Figures 4.5 through 4.8 are wind rose plots for the four stations. The wind rose plots show the frequency at which the wind comes from different directions. For Bakersfield, the predominant wind direction is from the northwest, with winds from the east a significant period of time. For Bradenton, the predominant wind direction is from the east, with winds from the northwest a significant period of time. For Tallahassee, the predominant wind direction is from the north, with winds from the south a significant period of time. For Ventura, the predominant wind direction is from the southwest, with winds from the east and northeast a significant period of time. Ventura has the least variability in wind direction of all of the stations.

Figure 4.3. Distribution of Daily Average Wind Speeds at the Meteorological Stations

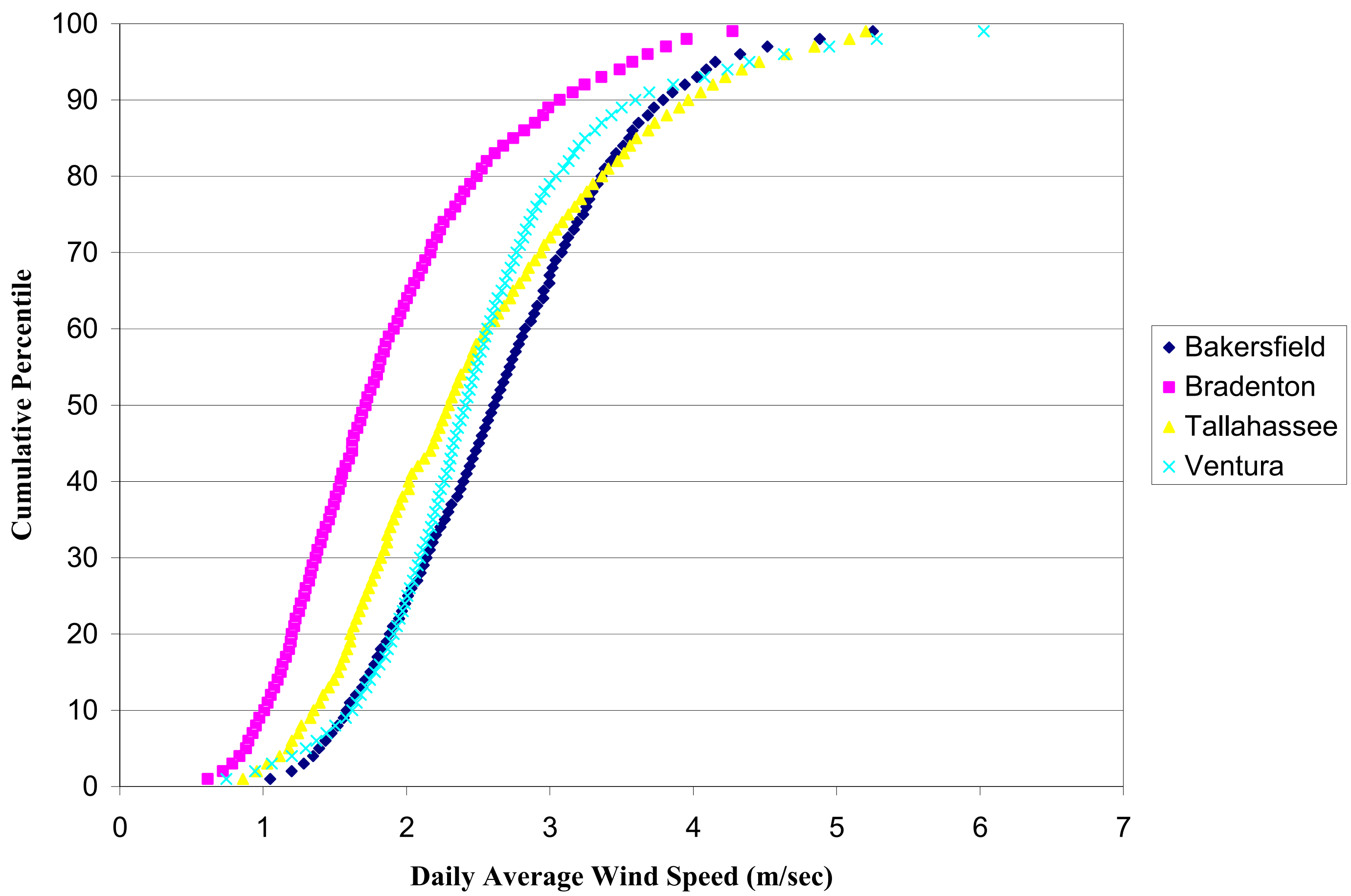


Figure 4.4. Frequency Distribution of Stability Classes at the Meteorological Stations

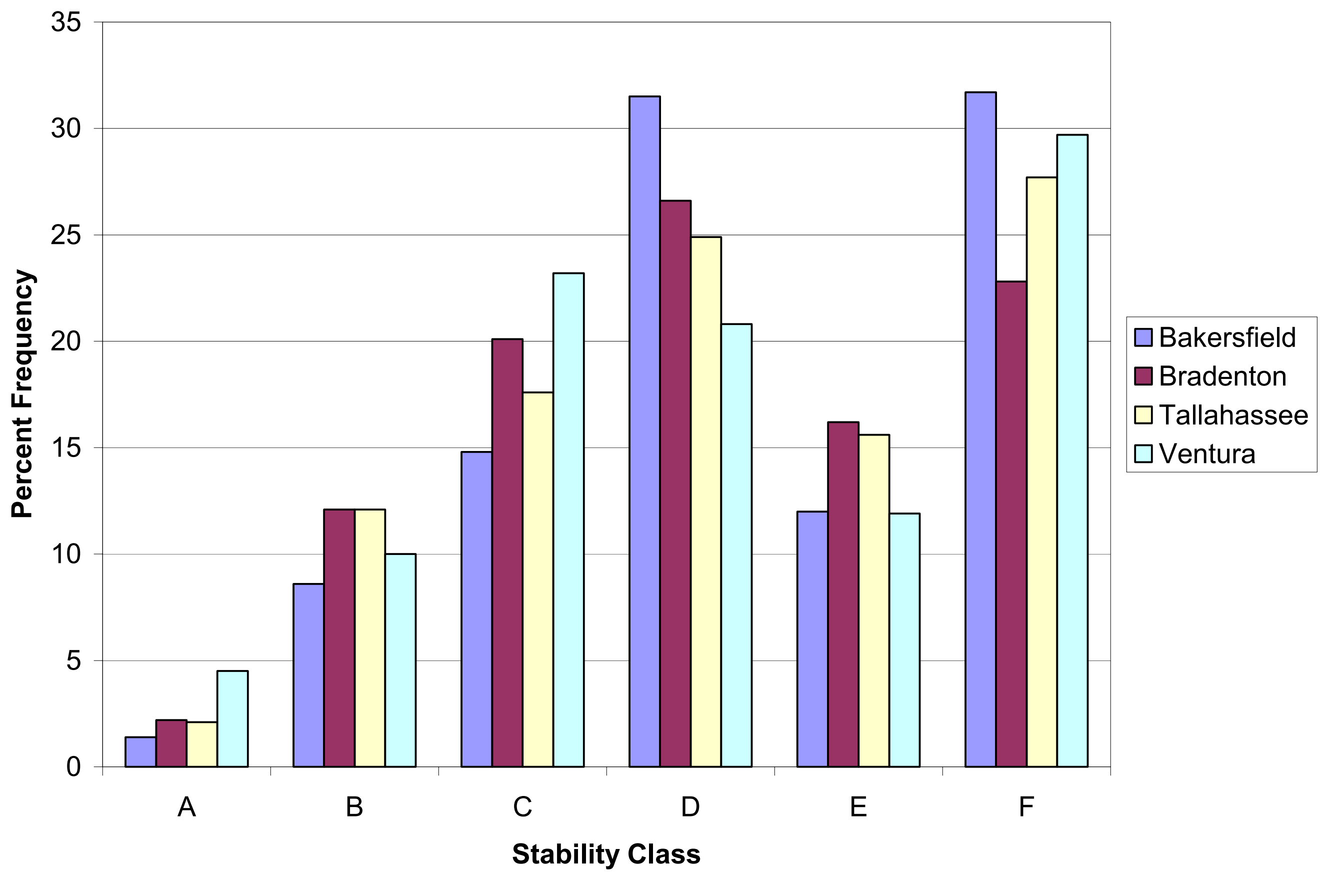


Figure 4.5. Wind Rose Plot for Bakersfield

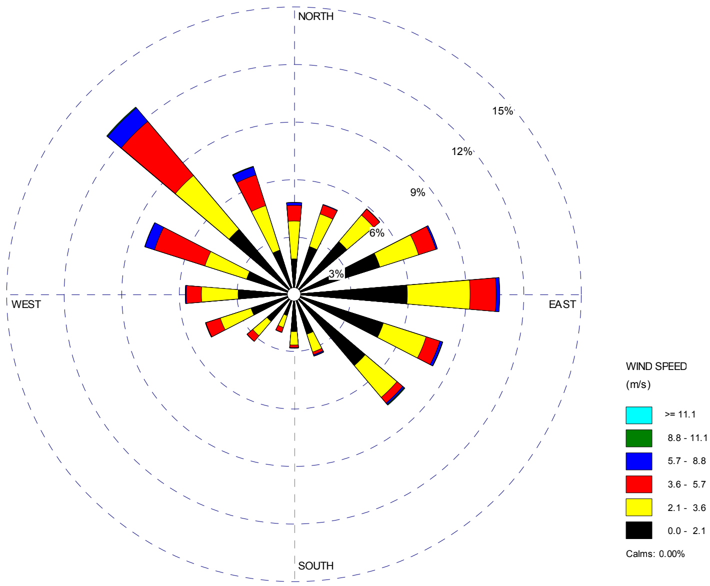


Figure 4.6. Wind Rose Plot for Bradenton

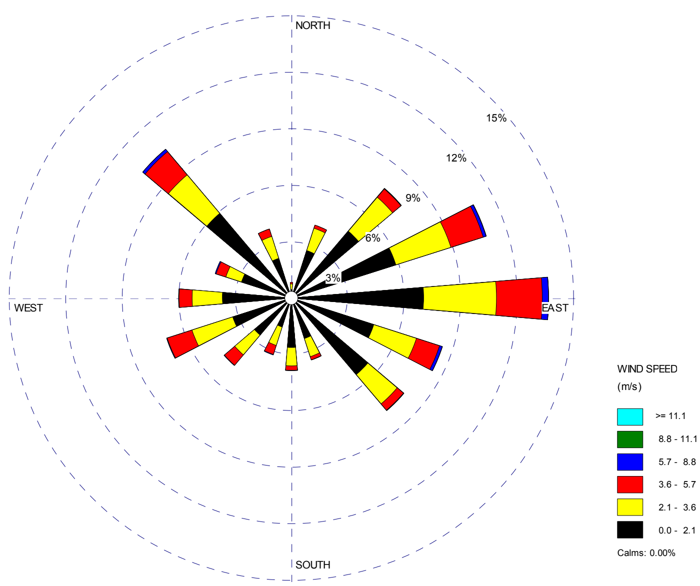


Figure 4.7. Wind Rose Plot for Tallahassee

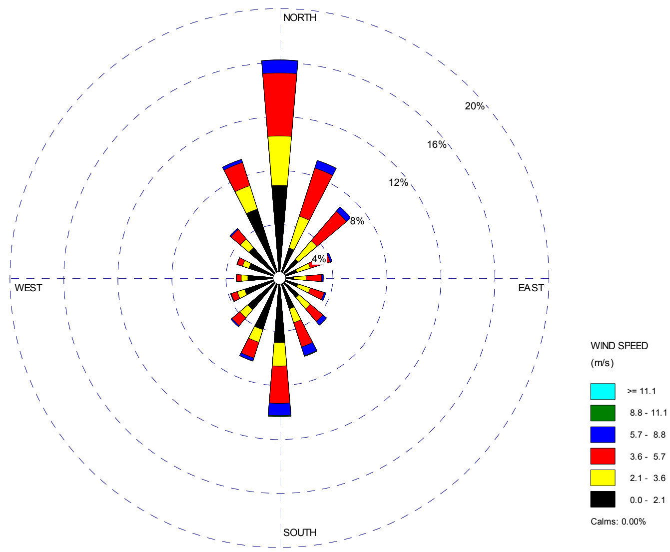
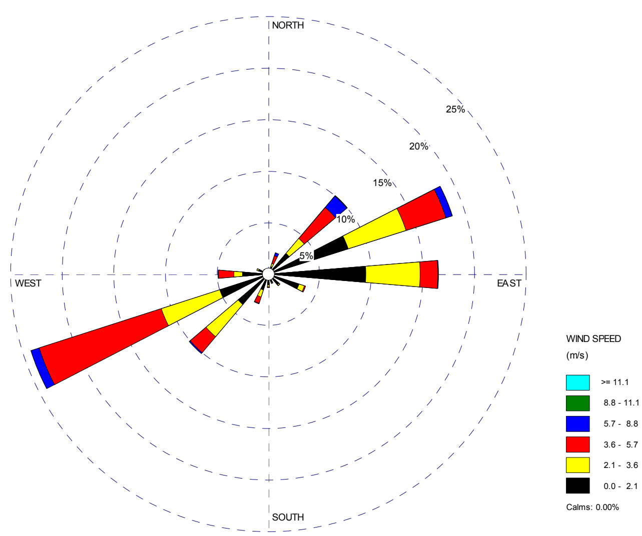


Figure 4.8. Wind Rose Plot for Ventura



4.7 Replacement of missing data

For regulatory modeling analysis, EPA requires 100% data completeness, and has developed a recommended methodology for replacing (or estimating) missing data (EPA, 1992). The methodology calls for missing data points to be estimated as the average of the nearest four hours for wind speed and wind direction, if those points are not also missing. Other procedures are recommended for other types of missing variables. Additionally, subjective procedures are recommended when the objective procedures do not work. If the objective procedures did not work, the data were reviewed manually. If there were data points near the missing data point, a reasonable average was calculated from the adjacent points. When there were large periods of missing data (e.g., several missing hours in a row), the average of the data for the same hours from the day before and after were used (Dennis Atkinson, EPA, personal communication, 2004). In a few rare cases where data were missing over more than a 24-hour period, the data from the day before or after a missing period were copied to achieve 100% data completeness. All of the changes that were made are documented in files on CD-ROMs provided with the report.

For the Bradenton FAWN data set, the percentage of missing data was 0.6% for wind speed, 0.5% for solar radiation, 0.5% for temperature, and 0.5% for wind direction. These numbers are based on the hourly data. The numbers differ significantly from the value in Table 4.4 because that value is based on the number of complete days, so one missing hour counted as a missing day. Most of the missing data for the FAWN were isolated, single hours and were easily replaced with the EPA procedures.

For Bakersfield ASOS data set, the percentage of missing data was less about 0.3% for all variables on an hourly basis. Therefore, only a very small amount of data needed to be replaced.

5.0 RESULTS OF THE MODELING ANALYSIS

5.1 Summary of Buffer Zone Estimates

Table 5.1 summarizes the buffer zones estimates using the 95th percentile of the distribution from PERFUM, and **Table 5.2** summarizes buffer zone estimates using the 90th percentile. For each flux study, there are separate results for each meteorological station and each field size (i.e., a total of 20 buffer zone estimates for each flux study). The highest buffer zone estimates were for the Oxnard raised bed studies, with average buffer estimates (average of the four meteorological stations) of 273 feet for Oxnard for a 1 acre field using the 95th percentile. The lowest estimates were for Camarillo drip irrigation (180 feet at 1 acre using the 95th percentile). The estimates assuming the 95th percentile are about 30-50% higher than the estimates assuming the 90th percentile. Some of the differences between the studies were the result of the diurnal profile of the emissions, which is discussed below.

Among the meteorological stations, the results using the Bradenton meteorological dataset were consistently higher. Generally, the results with the Bakersfield meteorological dataset were the lowest. The results with the Ventura and Tallahassee stations were in the middle and were relatively similar to one another.

As would be expected, the buffer zones were higher with larger field sizes. For the different field sizes, the average buffer zone estimates assuming the 95th percentile ranged as follows: (1) 1 acre: 154-273 feet, (2) 5 acre: 468-758 feet, (3) 10 acre: 725-1163 feet, (4) 20 acre: 1117-1777 feet, and (5) 40 acre: 1719-2761 feet. Assuming the 90th percentile, the buffer zones estimates ranged as follows: 1) 1 acre: 102-180 feet, (2) 5 acre: 333-531 feet, (3) 10 acre: 517-821 feet, (4) 20 acre: 797-1266 feet, and (5) 40 acre: 1222-1952 feet.

Some of the difference in results can be explained by the diurnal profile of the emissions, with the differences in the profile caused by the application timing. Generally, the atmosphere is most conducive to dispersion during the daytime, and the field emissions are highest immediately after the application. Therefore, early applications result in more of the emissions occurring during the period where conditions are most conducive to dispersion.

Table 5.1. Summary of Buffer Zones Estimates (feet) at the 95th Percentile Using the PERFUM Approach

Flux Data Source	Meteorological Station	Buffer Zone Estimate at the 95th Percentile (feet)				
		1 Acre	5 Acres	10 Acres	20 Acres	40 Acres
Manteca/flat fume	Bakersfield	207	545	810	1214	1824
	Bradenton	299	741	1102	1624	2408
	Tallahassee	230	636	974	1490	2293
	Ventura	249	646	961	1430	2142
	Average	***246***	***642***	***962***	***1439***	***2167***
Watsonville/flat fume	Bakersfield	154	426	646	974	1479
	Bradenton	233	590	879	1299	1925
	Tallahassee	180	515	794	1214	1870
	Ventura	190	502	748	1118	1666
	Average	***189***	***508***	***767***	***1151***	***1735***
Oxnard/raised bed	Bakersfield	246	702	1096	1690	2654
	Bradenton	341	899	1348	2037	3140
	Tallahassee	233	673	1043	1604	2490
	Ventura	285	860	1348	2136	3432
	Average	***273***	***758***	***1163***	***1777***	***2761***

Flux Data Source	Meteorological Station	Buffer Zone Estimate at the 95th Percentile (feet)				
		1 Acre	5 Acres	10 Acres	20 Acres	40 Acres
Plant City/raised bed	Bakersfield	115	390	613	954	1476
	Bradenton	207	561	846	1276	1929
	Tallahassee	138	436	679	1050	1627
	Ventura	157	485	761	1187	1843
	Average	***154***	***468***	***725***	***1117***	***1719***
La Selva Beach/drip irrigation	Bakersfield	220	692	1086	1683	2660
	Bradenton	295	787	1184	1797	2716
	Tallahassee	223	659	1023	1571	2447
	Ventura	246	686	1059	1624	2503
	Average	***246***	***706***	***1088***	***1669***	***2581***
Camarillo/drip irrigation	Bakersfield	144	413	630	964	1469
	Bradenton	230	597	889	1325	1981
	Tallahassee	164	482	745	1141	1758
	Ventura	180	512	784	1194	1817
	Average	***180***	***501***	***762***	***1156***	***1756***

Table 5.2. Summary of Buffer Zones Estimates (feet) at the 90th Percentile Using the PERFUM Approach

Flux Data Source	Meteorological Station	Buffer Zone Estimate at the 90th Percentile (feet)				
		1 Acre	5 Acres	10 Acres	20 Acres	40 Acres
Manteca/flat fume	Bakersfield	164	436	656	978	1463
	Bradenton	220	554	820	1211	1788
	Tallahassee	161	459	702	1070	1627
	Ventura	177	482	728	1093	1631
	Average	***180***	***483***	***727***	***1087***	***1627***
Watsonville/flat fume	Bakersfield	115	331	502	754	1141
	Bradenton	167	433	646	954	1414
	Tallahassee	118	361	558	853	1309
	Ventura	128	367	554	833	1250
	Average	***132***	***373***	***565***	***849***	***1278***
Oxnard/raised bed	Bakersfield	171	538	840	1299	2018
	Bradenton	217	584	879	1329	1995
	Tallahassee	148	459	715	1102	1709
	Ventura	177	541	850	1335	2090
	Average	***178***	***531***	***821***	***1266***	***1952***

Flux Data Source	Meteorological Station	Buffer Zone Estimate at the 90th Percentile (feet)				
		1 Acre	5 Acres	10 Acres	20 Acres	40 Acres
Plant City/raised bed	Bakersfield	82	302	476	741	1151
	Bradenton	141	394	594	895	1342
	Tallahassee	85	302	472	735	1138
	Ventura	98	335	525	817	1256
	Average	***102***	***333***	***517***	***797***	***1222***
La Selva Beach/drip irrigation	Bakersfield	148	489	774	1200	1870
	Bradenton	190	508	768	1148	1719
	Tallahassee	134	420	656	1014	1571
	Ventura	151	440	676	1033	1574
	Average	***156***	***464***	***718***	***1099***	***1683***
Camarillo/drip irrigation	Bakersfield	112	331	512	777	1187
	Bradenton	167	440	656	977	1450
	Tallahassee	112	344	535	820	1260
	Ventura	125	377	581	886	1348
	Average	***129***	***373***	***571***	***865***	***1311***

The diurnal effect is most apparent for the raised bed results. **Figure 5.1** shows the diurnal profile of the emissions for the Oxnard and Plant City raised bed studies. Both studies resulted in similar mass losses over the first 24 hours; however, the buffer zones for Oxnard are significantly higher. For example, using the Ventura meteorology and 95th percentile buffer zone, the buffer zone estimate for Oxnard was 860 feet and the buffer zone estimate for Plant City was 485 feet. As shown in Figure 5.1, the Plant City application started earlier at 7:38am and finished by 9:00am. By contrast, the Oxnard application started at 12:08pm and finished at 7:58pm. The mid-day start in the Oxnard study, rather than an early morning start, was due to logistical issues associated with setting up the study. Also, the prolonged application time was due to operational limitations of the research unit used for the application. At Plant City, the flux rate was high at the beginning of the application but dropped significantly by the early evening. At Oxnard, the emission rate was still significant through the nighttime period. This shows that if applications can be finished early, lower buffer zones can be justified.

The diurnal effect is also dramatic for the drip irrigation studies as shown in **Figure 5.2**. The La Selva Beach study started at 12:00pm and finished at 5:41pm, while the Camarillo study started at 8:08am and finished at 12:25pm. Compared from the start of application through the first 24 hours, the diurnal profile of the emissions for the two studies appears very similar. The total mass loss over 24 hours was higher at La Selva Beach compared to Camarillo. Nevertheless, the buffer zone estimates for Camarillo are significantly lower than for La Selva Beach. For example, for the Ventura meteorology and the 95th percentile buffer zone for a 5 acre field, the buffer zone for La Selva Beach was 706 feet, and the buffer zone estimate for Camarillo was 501 feet. At La Selva Beach, there were still high flux rates into the late evening (through 10pm). At Camarillo, peak flux rates ended by 3pm. Therefore, more of the La Selva Beach emissions occurred during the evening period that is less conducive to dispersion.

For the two flat fume studies (Manteca and Watsonville), the results were more comparable, but the Manteca study gave higher results by about 25%. Most of the reason for the buffer zone difference is that the mass loss over 24 hours was higher for Manteca (47%) compared to Watsonville (35%). Both applications were finished in the morning, although the Manteca study was finished later in morning (11:45am for Manteca compared to 7:54am for Watsonville). However, the diurnal effect does not appear to be as significant as the other studies. Another difference between the studies is that there were fewer measurement periods for Watsonville. The first 12-

hours were characterized by only one measurement, compared with three at Manteca. This allowed a fuller characterization of the daytime emissions profile at Manteca.

Figure 5.1. Comparison of the Diurnal Profiles for the Raised Bed Studies (Shaded circles show the start of application, and open circles show the end)

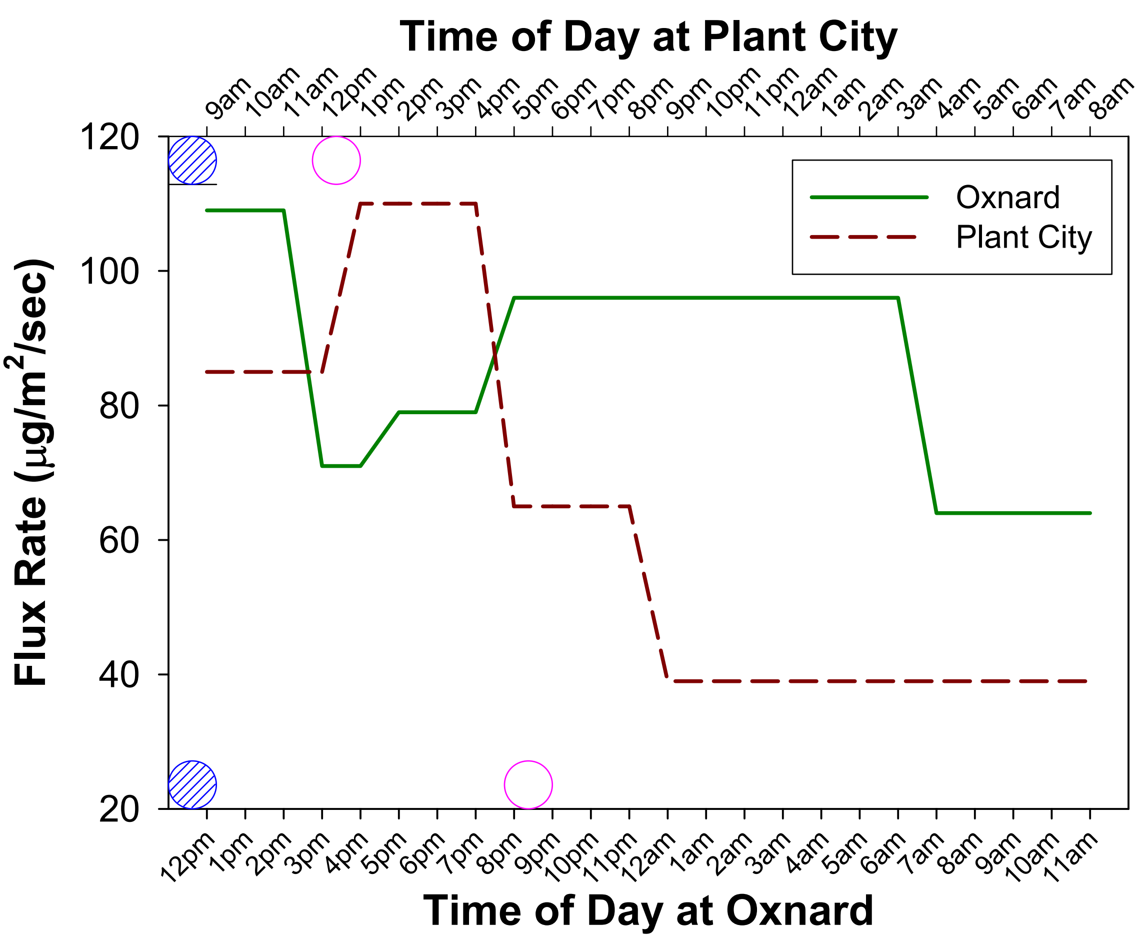


Figure 5.2. Comparison of the Diurnal Profiles for the Drip Irrigation Studies (Shaded circles show the start of application, and open circles show the end)

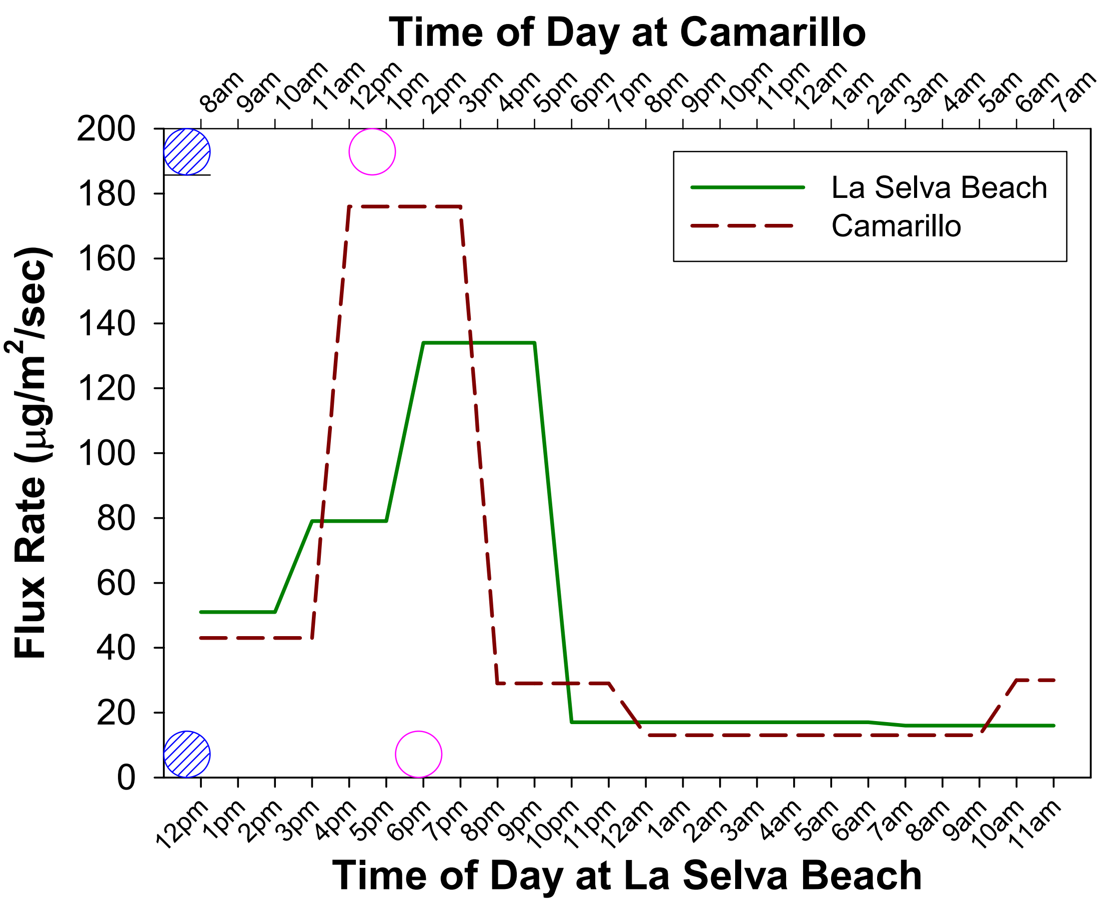
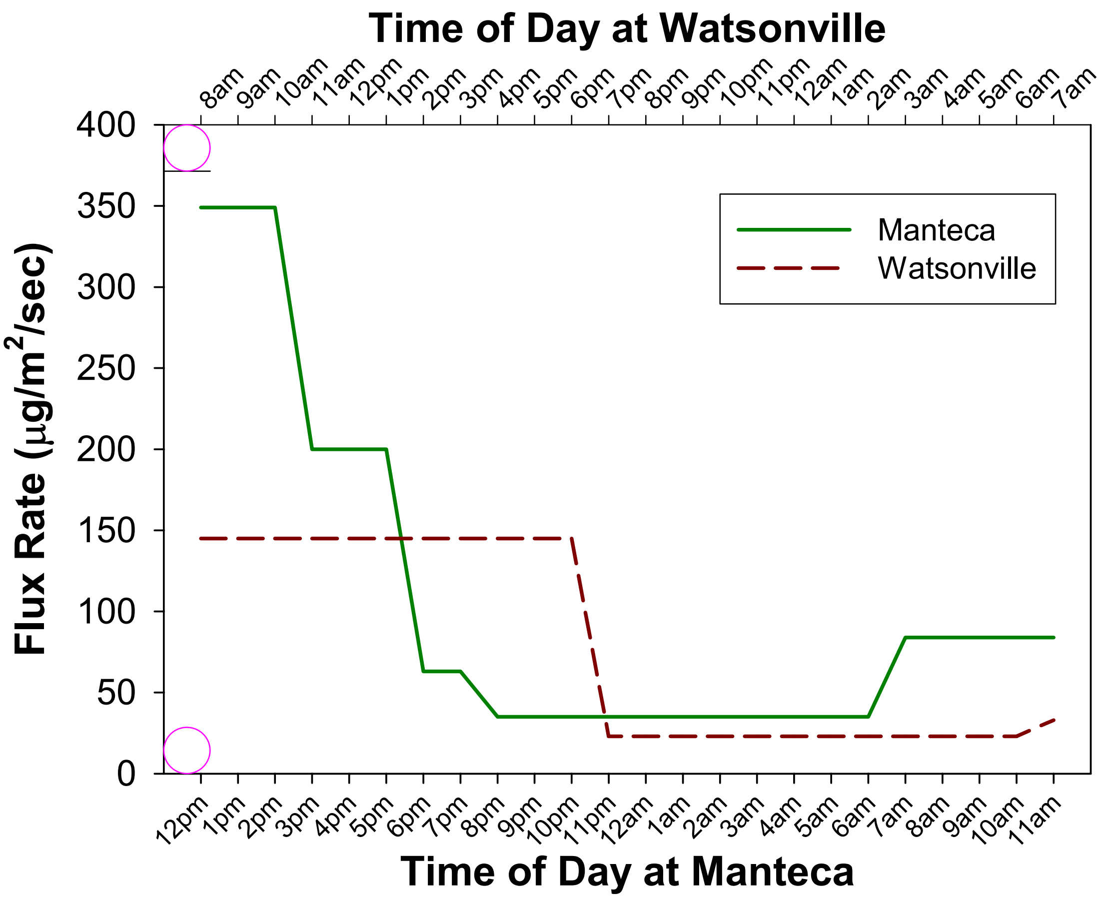


Figure 5.3. Comparison of the Diurnal Profiles for the Flat Fume Studies
(Open circles show the start and end of the application)



5.2 Margin of exposure analysis

The PERFUM toolbox also includes the PERFUM_MOE program, which estimates the margin of exposure distribution for a given buffer zone. In other words, it constructs a distribution of margins of exposure (given all the earlier caveats related to the upper-bound nature of the estimates) for someone at the perimeter of the buffer zone for 24-hours. **Figures 5.4 and 5.5** show examples of the margin of exposure curve for 5 and 10 acres fields using both the 90th and 95th percentiles to establish the buffer zones. The figures show that the margin of exposure curve is not steep for this situation, unlike other environmental exposures where there can be very large differences between the 90th and 95th percentile and percentiles above that. The MOE curves for other scenarios are similar for Figures 5.4 and 5.5.

The goal of the buffer zone analysis is to ensure that a certain percentile of locations at the perimeter of the buffer have at least 100-fold margins of exposure, the risk assessment goal for iodomethane. For example, when using the 95th percentile buffer zone, the goal is to have at least 95% of the locations with 100-fold margins of exposure[9]. However, for risk managers, it is also useful to know what the margins of exposure may be for the remaining 5% of the locations. Figure 5.4 shows that at the 99th percentile, there is a 49-fold margin of exposure for the 95th percentile buffer zone, and a 31-fold margin of exposure. Therefore, 99% of the locations will have at least a 51-fold or 31-fold margin of exposure. For the 95th percentile buffer zone, the MOE was >32 for 99.9% of the locations and >24 for 99.99% of the locations. For the 90th percentile buffer zone, the MOE was >21 for 99.9% of the locations and >16 for 99.99% of the locations.

The example for the 10 acre field in Figure 5.5 is even less steep. The graph shows that at 99% percentile the locations, there is a 65-fold MOE or higher for the 95th percentile buffer zone, and a 53-fold MOE or higher for the 90th percentile buffer zone. For the 95th percentile buffer zone, the MOE is >45 for 99.9% of the locations and >36 for 99.99% of the locations. For the 90th percentile buffer zone, the MOE is >37 for 99.9% of the locations, and >30 for 99.99% of the locations.

[9] Due to the geometry of the calculation, the PERFUM_MOE program can give slightly different results at the percentile of interest. In the examples in the figures, the MOE is 99 at the 90th and 95th percentiles, instead of 100.

Figure 5.4. Margins of Exposures for a 5 Acre Field with Oxnard Flux Rates and Ventura Meteorology and the 90th and 95th Percentile Buffer Zones

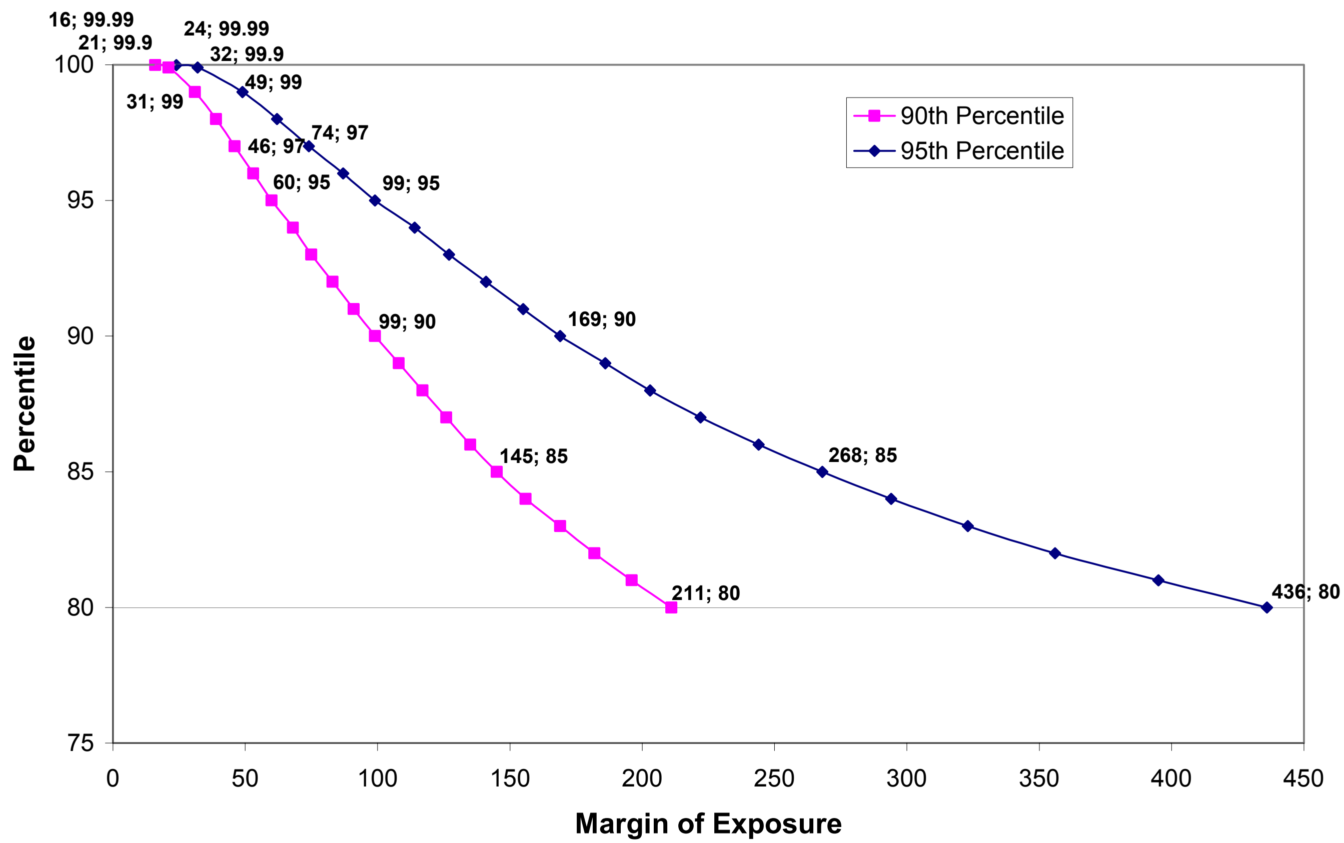
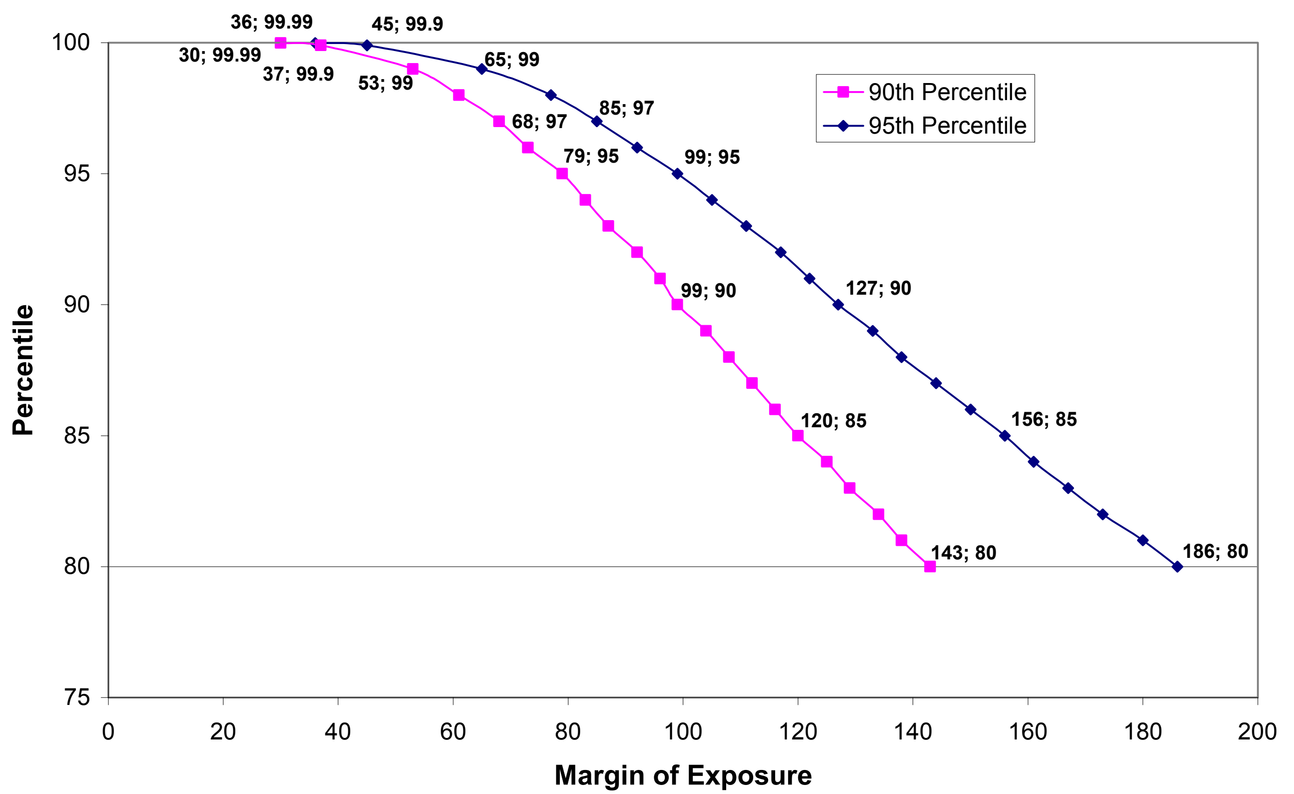


Figure 5.5. Margins of Exposures for a 10 Acre Field with Manteca Flux Rates and Bakersfield Meteorology and the 90th and 95th Percentile Buffer Zones



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5.3 Potential exposures on the day after application

The exposures on the day after application were modeled with the PERFUM_MOE program to determine the probability of exposures above the toxicity threshold on the second day after application. The results were modeled using the Manteca and Oxnard flux rates with each meteorological station. The analysis showed that exposures above the toxicity threshold would be rare on the second day. For all cases, more than 99% of the locations had margins of exposure greater than 100. For most scenarios, the margins of exposure were greater than 100 for 99.9% of the locations.

6.0 UNCERTAINTY ANALYSIS

6.1 Introduction

Any large modeling system such as the one described in this report will have various sources of uncertainty. Because the goal of the system is to develop health-protective buffer zones for regulatory purposes, the modeling system tends towards an overestimation of the risk when large uncertainties are present. This section is devoted to describing the major areas of uncertainty in the modeling system, and, when possible, quantifying the potential impact of uncertainty on the buffer zone estimates. The major areas of uncertainty include: (1) estimation of the flux rates, (2) characterization of the meteorology following applications, (3) air dispersion modeling, (4) indoor versus ambient exposure and time-activity patterns, (5) potential for exposure from multiple fields, and (6) variation of exposure and application likelihood by season. The next six subsections address each of the areas of uncertainty, and present sensitivity analyses, if possible, to quantify the potential effects of the uncertainties.

6.2 Flux rates

As discussed in Section 3.3, there are two ways to look at the error associated with the flux rates. First, there is a measurement error for each individual flux measurement study. This error is associated with the measurement method and specific to each individual study. It is largely dependent upon the accuracy of the dispersion modeling methodology to simulate the emission of the fumigant from the field, and the ability of the downwind measurements to characterize the downwind concentrations. Secondly, there is an error associated with using the available flux study measurements to characterize all of the possible conditions that could occur in an actual agricultural application for a particular application methodology. The flux rate of the fumigant is likely dependent on numerous factors such as the soil temperature, ambient temperature, soil type, organic matter content of the soil, and others. However, the effects of each of these factors have not been quantified for fumigants, and it would be very difficult to do.

The first source of error, the measurement error, was addressed by perturbing the flux rates for each measurement period in the model by the measurement error found in the flux study. The perturbation did not result in large differences in the estimates at the 95th percentile, but had somewhat larger differences at the higher percentiles.

To estimate the second source of uncertainty, the large source of data on potential field variability for methyl bromide was examined. The methyl bromide data are summarized in a memorandum prepared by CDPR entitled "Summary of off-site monitoring for methyl bromide field fumigations," January 21, 2000 (CDPR, 2000). The memorandum describes 44 flux studies for methyl bromide, which CDPR based its methyl bromide buffer zone analysis. These data were analyzed to estimate an overall uncertainty for the flux estimates in the iodomethane studies.

Table 1 of the CDPR memorandum summarizes the percent of methyl bromide that was emitted from the field after the first 24 hours. CDPR frequently refers to this value as the emissions ratio. Like iodomethane, the buffer zones for methyl bromide were based on a 24-hour toxicity value. We focused our analysis on broadcast (i.e., flat fume) and raised bed applications with tarps, consistent with the proposed practice for iodomethane. For broadcast, there were three types of tarps used, with varying abilities to prevent volatilization. The three tarps included "high barrier" (HB), "vary high barrier" (VHB), and "virtually impermeable film" (VIF), and these results are reported separately. The bed applications were kept separate from the broadcast applications as we are using separate factors for broadcast and raised bed in our modeling.

Table 6.1 summarizes the emission ratios from the CDPR memorandum. For broadcast applications with an HB tarp, there were 13 separate measurements. There were four, five, and nine measurements for broadcast/VHB, broadcast/VIF, and bedded applications, respectively. The emission ratios in the Arvesta studies range from 0.31 to 0.57, which represents a smaller range than the methyl bromide studies. Therefore, the coefficient of variance, as opposed to a straight standard deviation, appears to be the most appropriate way to use the methyl bromide data for the uncertainty analysis. The coefficient of variance was calculated for each of the four application types listed in Table 6.1, and the average CV was 47%.

For an uncertainty analysis, two scenarios were considered using the Manteca flux data and Tallahassee meteorological data as an example:

1) The CV of 47% was applied to all measurement periods, in place of the CV for the flux study individually.
2) Higher mean flux rates were assumed for all periods, corresponding to a 75th percentile with the emission ratio at Manteca as the mean and the CV of 47% representing the variance. The emission ratio at Manteca was 0.47, and the *z*-

score corresponding to a 75th percentile is about 0.7. Therefore, the 75th percentile emission ratio, based on the variability in the methyl bromide data, is 0.62, which is higher than any of the emission ratios measured in the Arvesta studies. For this scenario, the CVs that were used in the normal modeling runs, representing the measurement uncertainty in the flux study, were used. This scenario represents the situation if the Manteca flux measurements are not representative of flat fume applications of iodomethane generally.

Table 6.1. Emission Ratios for Methyl Bromide from CDPR Analysis

Replicate	Broadcast/ HB	Broadcast/ VHB	Broadcast VIF	Bed/HB
1	0.26	0.094	0.32	0.062
2	0.16	0.66	0.38	0.68
3	0.098	0.42	0.44	1
4	0.40	0.80	0.22	1
5	0.36		0.16	1
6	0.36			0.76
7	0.30			0.76
8	0.17			1
9	0.17			1
10	0.068			
11	0.26			
12	0.20			
13	0.48			
Mean	0.253	0.494	0.304	0.807
Standard Deviation	0.123	0.309	0.114	0.309
Coefficient of Variation	49%	63%	38%	38%

The results of the uncertainty analysis for the flux rates are summarized in **Table 6.2**. For uncertainty analysis no. 1, using a variance for the measurement uncertainty that is reflective of the methyl bromide data, the results did not change significantly from the normal PERFUM scenario. For field sizes at or below 20 acres, the uncertainty scenario results were higher, but no more than 3.1% higher compared to the normal scenario. At 40 acres, there was a larger difference (11.4%). These results are based on defining the buffer zone at the 95th percentile. At percentiles above the 95th, and particularly the 99th and above, the differences between the normal scenario and the uncertainty scenario are larger.

For uncertainty scenario no. 2, assuming a higher flux rate based on the variability in the methyl bromide results, the differences were larger. The largest difference was for the 1 acre field, with the uncertainty scenario being 39.6% higher than the normal scenario. For the rest of the field sizes, the differences were about 25%. These results show that the buffer zones could be higher for different field conditions than were measured in the iodomethane studies conducted to date. However, although the sample size is small, the flux studies to date have given very similar results for the repeat studies of the same application rates (see Section 3). Also, there were large differences associated with the timing of the application (see Section 5). The differences associated with the application timing appear to be a larger factor than the uncertainty associated with the flux rates themselves.

Table 6.2. Results from Uncertainty Analysis for Emission Rates (Manteca Flux Rate Data with Tallahassee Meteorological Data)

Field Size (Acres)	Buffer Zone at the 95th Percentile (feet)		
	Normal PERFUM Scenario	Uncertainty Scenario No. 1	Uncertainty Scenario No. 2
1	230	236 (+2.6%)	321 (+39.6%)
5	636	656 (+3.1%)	804 (+26.4%)
10	974	1000 (+2.7%)	1233 (+26.6%)
20	1490	1525 (+2.3%)	1876 (+25.9%)
40	2293	2556 (+11.4%)	2886 (+25.9%)

6.3 Meteorology

The variability associated with meteorology can result in different buffer zone estimates by season and location. Later in this section, separate buffer zone estimates are provided for each month of the year for a subset of the flux data. The results show that the highest buffer zones are generally in the wintertime, when there are generally lower wind speeds, greater atmospheric stability, and a shorter daytime period. However, the differences in buffer zone estimates by season were not that substantial. Nonetheless, applications are generally more frequent in the warmer weather periods, so the use of meteorological data over the entire year should yield a conservative result.

There are also annual variations in meteorology. For example, air pollutant levels of criteria pollutants are known to vary on annual basis due to the effects of meteorological variability (EPA, 2003b). To account for annual variations in meteorology, the U.S. EPA recommends the use of five years of historical meteorological data for dispersion modeling analyses (EPA, 1999a). This recommendation was followed for this analysis, and should be sufficient to account for annual variability.

6.4 Air dispersion modeling

6.4.1 General accuracy of air dispersion modeling

Schnelle and Dey (1999) summarize the findings of a 1977 American Meteorological Society review of Gaussian dispersion models. For ideal circumstances, where there is uniform terrain, steady meteorology, with source and ambient parameters measured by research-grade instruments, the observed maximum downwind ground-level concentration should be within 10-20% of the estimated value for a ground-level source. For applications where the meteorological parameters are from a non-on-site station, the accuracy is within a factor of two. The applications considered in the current report more closely represents the ideal circumstance. The terrain for actual field applications is unknown but the potential variability is limited if the buffer zones are relatively close to the field. The flux determinations were made using measurements from on-site meteorological stations. However, the concentration estimates in this report are used to represent all possible meteorological circumstances in the real world. While a range of meteorological stations were considered in this analysis, there is meteorological variability that cannot be accounted by this method. Another factor that must be considered is that the fluxes were determined from a back-calculation, which essentially calibrates the model to this particular circumstance. Therefore, the accuracy of the model for this application is likely closer to the 10-20% value than the factor of two. However, putting a more quantitative value on the uncertainty is not possible.

The American Meteorology Society (AMS)/EPA Regulatory Model Improvement Committee (AERMIC) recently conducted a modeling evaluation for the proposed ISC replacement model AERMOD (AERMIC, 1998). AERMIC is a joint venture of the AMS and EPA that is building and evaluating AERMOD. As part of this evaluation, AERMIC also included model evaluation results for ISCST3. The model evaluation made use of several historical tracer gas studies. In these studies, an inert tracer gas (SF_6) was released from an actual source, and the concentrations of the tracer were measured downwind. Both ISCST3 and AERMOD were applied for the source and the predictions compared to the tracer concentrations. Additionally, the model evaluation included several long-term SO_2 monitoring databases, which are also useful for model evaluation.

Table 6.3 summarizes the model evaluation results from AERMIC that apply to ISCST3. The evaluation statistic is the robust highest concentration, which is a statistical estimator of the highest concentration which reduces the impact of extreme values on the model comparison. The table shows the ratio of the modeled to observed concentrations for different averaging periods.

Table 6.3. Results from AERMIC model evaluation for ISCST3

Model evaluation study	Description of source and terrain	Ratio of the modeled/observed robust highest concentrations[1]
Prairie Grass (SO_2)	Flat grassy field, non-buoyant source, near surface release	1.5 (1-hour average)
Kincaid (SO_2)	Flat rural field, highly buoyant source, tall stack	0.68 (1-hour average)
Kincaid (SF_6)	Flat rural field, highly buoyant source, tall stack	0.56 (3-hr average) 0.45 (24-hour average) 0.14 (annual peak)
Baldwin (SO_2)	Flat rural field, highly buoyant source, tall stack	1.48 (3-hour average) 1.13 (24-hour average) 0.63 (annual peak)
Indianapolis (SF_6)	Flat urban field, highly buoyant source, tall stack	1.30 (1-hour average)
Clifty Creek (SO_2)	Moderately hilly terrain, rural, highly buoyant source, tall stack	0.98 (3-hour average) 0.67 (24-hour average) 0.31 (annual peak)
Martins Creek (SO_2)	Highly hilly terrain, rural, highly buoyant source, tall stack	7.25 (3-hour average) 8.88 (24-hour average) 3.37 (annual peak)
Lovett (SO_2)	Highly hilly terrain, rural, highly buoyant source, tall stack	8.20 (3-hour average) 9.11 (24-hour average) 7.49 (annual peak)
Westvaco (SO_2)	Highly hilly terrain, rural, highly buoyant source, tall stack	8.50 (3-hour average)

[1] The robust highest concentration (RHC) is a statistical estimator for the highest concentration. It is determined from a tail of the exponential fit to the high end of the frequency distribution of observed and predicted values.

The results in Table 6.3 shows that the ratio of the modeled to observed concentrations for all of the comparisons ranged from 0.14 (a 7-fold underprediction) to 9.11 (an 8-fold overprediction), depending on the model evaluation study and the averaging period. The most appropriate averaging period for this report is the 24-hour average. The comparisons for a 24-hour average ranged from 0.45-9.11, similar to the overall range. The worst results were for Martins Creek, Lovett, and Westvaco, where ISCST3 significantly overpredicted the observed concentrations. All of these locations had highly hilly terrain. For flat or moderately hilly terrain sites, the predictions were within about 50% of the observed concentrations for the 24-hour average. The most similar comparison for this report is at Prairie Grass. In this study, a non-buoyant source was released near the surface into flat grassy terrain. The ISCST3 model overpredicted the observed concentrations by 50%.

There are several reasons why the use of ISCST3 for fumigant applications may be more accurate than many of the model comparisons detailed in Table 6.3:

- Fumigants are modeled as area sources and are not buoyant, meaning that they are released at ambient temperatures. For most of the studies in Table 6.3, the sources were tall stacks with buoyant plumes. The buoyancy requires the use of plume rise algorithms to simulate the rising of the hot plume into a cooler atmosphere. These plume rise algorithms, and other aspects of modeling a stack gas result in uncertainties in the modeling process that are not part of a fumigant application.

- The receptor area for the fumigant applications is relatively close to the field compared to a tall stack situation. For tall stacks, the plume will travel some distance (sometimes miles) before mixing down to the surface. The simulation of the plume traveling from the source to the receptor points creates uncertainties due to plume meandering with the wind, the influence of obstructions such as building, the influence of terrain, and the need to model dispersion over a significant distance. There are fewer unknowns when modeling a fumigant application to receptors that are close to the source.

- The flux rates for the fumigant applications are estimated from a back-calculation of the ISCST3 model with actual field measurements. Therefore, the flux rates are essentially calibrated to the ISCST3 model. While from a pure scientific standpoint there could be drawbacks to this approach, from a regulatory perspective, this approach reduces the uncertainty of using the ISCST3 model to establish the buffer zones.

It is not possible to provide a firm value for the uncertainty of using ISCST3 for modeling fumigant applications, but the discussion in this section suggests that the model accuracy is likely significantly better than a factor of two.

6.4.2 Calm winds

The treatment of calm winds has always been problematic in dispersion models. Calm winds occur when the wind speed is too low to be detected by the wind sensor, and the threshold is generally about 1 m/sec. The general Gaussian formulation of the ISCST3 model has the concentration predictions inversely proportional to the wind speed. The model developers found that there were significant overpredictions for calm winds. One reason may be that the wind direction is highly variable during calm conditions (i.e., "light and variable" winds). Therefore, the model, in its regulatory default mode, has what is called a "calms processing routine" (EPA, 1995). If the model encounters a calm wind, the hour is skipped and not modeled. The average concentration for any period includes only the non-calm hours.

CDPR has suggested that ISCST3 may underestimate concentrations because "calm conditions are not simulated by ISCST3" (Johnson, 2001, p.16). However, it is not completely accurate to imply that ISCST3 does not simulate concentrations for non-calm conditions, and whatever higher concentrations that occur during calm conditions are not accounted for. Presumably, the calms processor routine was found to adequately simulate concentrations by ISC developers. The model evaluations presented in the last subsection included the use of historical meteorological datasets which presumably include calm periods, but there was no apparent bias towards underprediction. Furthermore, the back-calculation method of estimating the flux rates calibrates the model to the actual field data, which were collected during some calm conditions. Therefore, the use of calms processing is not likely to result in significant underpredictions for the ISCST3 model.

6.4.3 Terrain

For methyl bromide, CDPR requires larger buffer zones for sloped fields under certain weather conditions[10]. On calm, clear nights, cold air drainage can occur, which can result in cold air moving downhill due to differences in density. The calculations in this report do not account for this scenario.

[10] CDPR Guidance Manual for Methyl Bromide Field Soil Fumigation.

6.5 Indoor versus outdoor exposure and time activity patterns

The buffer zone calculations in this report assume that a person is at the perimeter of the buffer zone and outdoors for 24 hours. Both of these assumptions, particularly considered jointly, would represent very rare occurrences. However, it is very difficult to quantitatively estimate the amount of time an individual may actually spend at the perimeter of a buffer zone in a 24-hour period. Also, there are no available data on indoor air concentrations of iodomethane. However, there is evidence that methyl bromide, a similar chemical, is adsorptive and it is being used as a means of disinfecting indoor environment for Anthrax[11]. Therefore, it is possible that iodomethane may have a reduced concentration in indoor environments compared to ambient air.

To understand the potential impact of indoor air exposure, we considered two simple scenarios using the Manteca flux data with the Ventura meteorological data and a 5 acre field:

- Maximum exposure scenario: Normal scenario where a person spends 24-hours at the perimeter of the buffer zone outdoors.
- Alternative Scenario 1: For the nighttime period, 8PM-8AM, a person is indoors and the indoor concentration is 70% of the outdoor concentration (I/O ratio of 0.7).
- Alternative Scenario 2: For the 8PM-8AM, a person is indoors and the indoor concentration is 30% of the outdoor concentration.

The results are presented in **Table 6.4**. For alternative scenario no. 1 (I/O=0.7), the buffer distance at the 95th percentile was 597 feet compared to 646 feet for the maximum scenario (7% lower). For alternative scenario no. 2 (I/O=0.3), the buffer distance at the 95th percentile was 545 feet, which was 16% lower than the maximum exposure scenario.

[11] See: http://www.epa.gov/epahome/hi-anthrax.htm#NEWMETHODSANDTECHNOLOGIES

Table 6.4. Buffer Distances for Different Indoor/Outdoor Concentration Ratios with Manteca Flux Data, Ventura Meteorological Data and a 5 Acre Field

Exposure Scenario	Description	95th Percentile Buffer Distance (feet)
Maximum Exposure	Outdoors 24-hrs/day	646
Alternative Scenario 1	Indoors from 8PM-8AM (indoor exposure factor = 0.7)	597
Alternative Scenario 2	Indoors from 8PM-8AM (indoor exposure factor = 0.3)	545

To understand the additional impact of someone not spending the whole 24-hour period at the perimeter of the buffer zone, we considered two additional scenarios:

- Alternative Scenario 3: Someone is away from the field (at a significant distance so they are not exposed) from 8AM-5PM (e.g., a workday).
- Alternative Scenario 4: In addition to being away from the field from 8AM-5PM, the person is indoors from 8PM-8AM and the indoor concentration is 50% of the outdoor concentration. The person is assumed to be outdoors, only from 5PM-8PM, which is not an atypical situation, given that people spend about 90% of their time indoors, on average.

The results for these tests were more dramatic and are presented in **Table 6.5**. For alternative scenario no. 3, the buffer distance was reduced to 423 feet from 646 feet (a 34% reduction). For alternative scenario no. 4, the buffer distance was reduced to 249 feet (a 61% reduction).

Table 6.5. Buffer Distances for Different Indoor/Outdoor Concentration Ratios and Time Activity Patterns with Manteca Flux Data, Ventura Meteorological Data and a 5 Acre Field

Exposure Scenario	Description	95th Percentile Buffer Distance (ft)
Maximum Exposure	Outdoors 24-hrs/day	646
Alternative Scenario 3	Away from Field from 8AM-5PM	423
Alternative Scenario 4	Away from Field from 8AM-5PM; Indoors from 8PM-8AM (indoor exposure factor = 0.5)	249

While it is certainly true that most people will not spend all 24-hours of the first post-application period outside and at the buffer zone perimeter, it is difficult to quantify the actual time-activity patterns and indoor air data are not available. However, this analysis, showing a range of possibilities, makes clear that exposures calculated assuming a person spends 24-hours a day outside at the perimeter of a buffer zone are conservative.

6.6 Potential for exposure from multiple fields

Another potential factor that was not explicitly considered in the analysis in this report is the possibility of multiple fields emitting at the same time. For example, there may be two or more farms in a particular area where applications occur in a similar time period. Also, in some cases, growers will divide their fields into several portions and apply each portion on consecutive days. For methyl bromide in California, the buffer zone is defined by the size of each of the field portions.

Modeling for exposure from multiple fields is complicated and several representative scenarios will be presented at the Science Advisory Panel (SAP) meeting using variations of the PERFUM software. However, several general points are worth making at this juncture:

- Whatever the ultimate impact of multiple fields is for iodomethane will substantially be driven by the final buffer zones, which will not be resolved until the toxicity value for iodomethane is finalized. For example, if the typical buffer zones are 200-300 feet, there is a significantly smaller probability of nearby fields adding significant concentrations within these buffer zones, than if the buffer zones were around a 1000 feet.

- Given the rapid decline of iodomethane emissions following application, the probability of a nearby field emitting significant quantities of iodomethane during an application would be expected to be small. However, it is not clear how this probability could be estimated.

- The geometry of field configurations also suggests only a small possibility of impacts across farms. There is typically a predominant wind direction in any location. Therefore, the maximum downwind concentration for a given field is unlikely to be significantly affected by another field, because the maximum impact from any other fields would not be downwind of the field in question for the range of possibilities in actual field environments.

6.7 Seasonal variation in applications

Figures 6.1 and 6.2 display the buffer zone results by the month of the application. In Figure 6.1, the results are presented with the PERFUM "whole field" approach of considering the exposure in all directions from the field, and the maximum daily concentration approach using the flux data from Camarillo and all four meteorological stations. Figure 6.2 provides the same results using the Manteca flux data. There is clearly an annual pattern in all of the results, with higher buffer zones occurring in the wintertime and lower buffer zones in the summertime. On average, the buffer zones in December are 50% higher than the buffer zones in June.

In peak usage areas, such as California, most applications occur in the summertime, which is ideal given that the conditions in the summertime are most conducive to dispersion. However, this annual pattern in applications is not true of all locations.

Figure 6.1. Buffer Lengths by Season for the PERFUM Approach and the Maximum Concentration Only Approach Using Flux Data from Camarillo

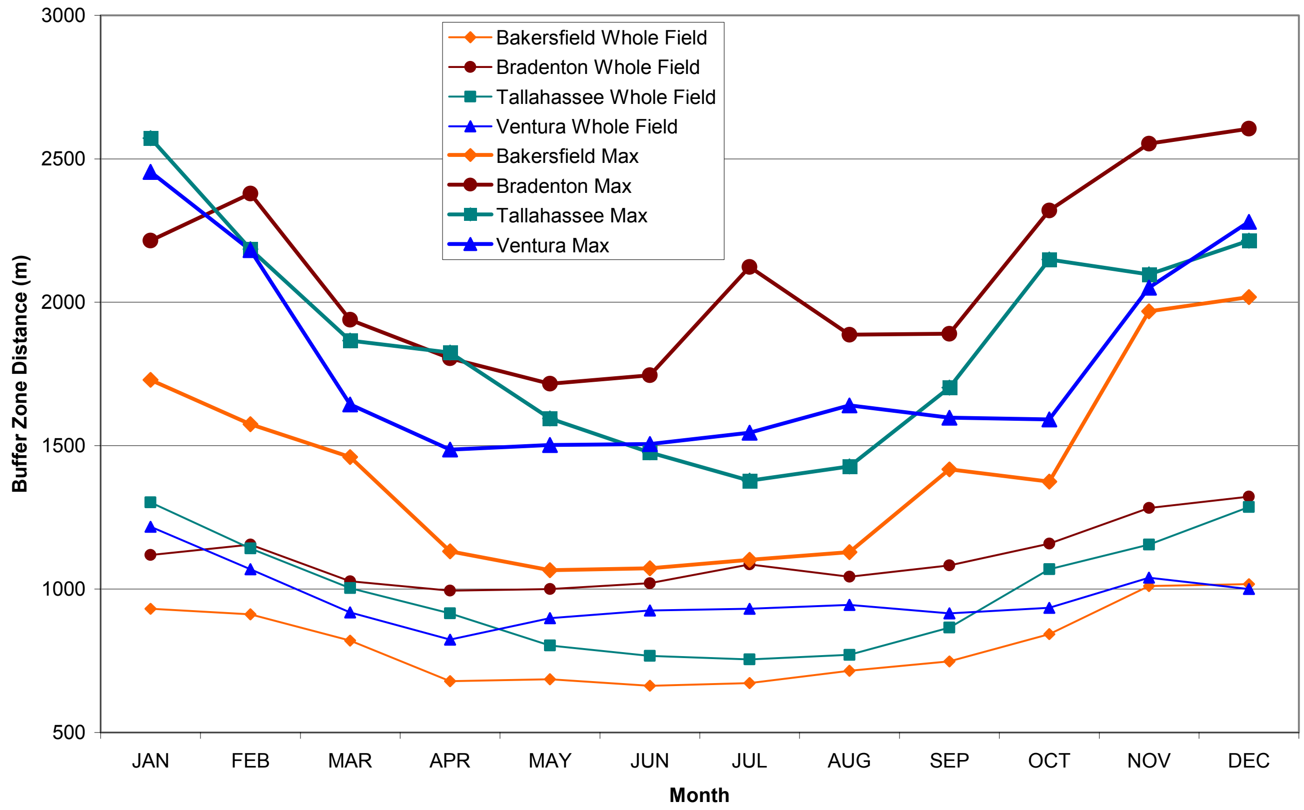
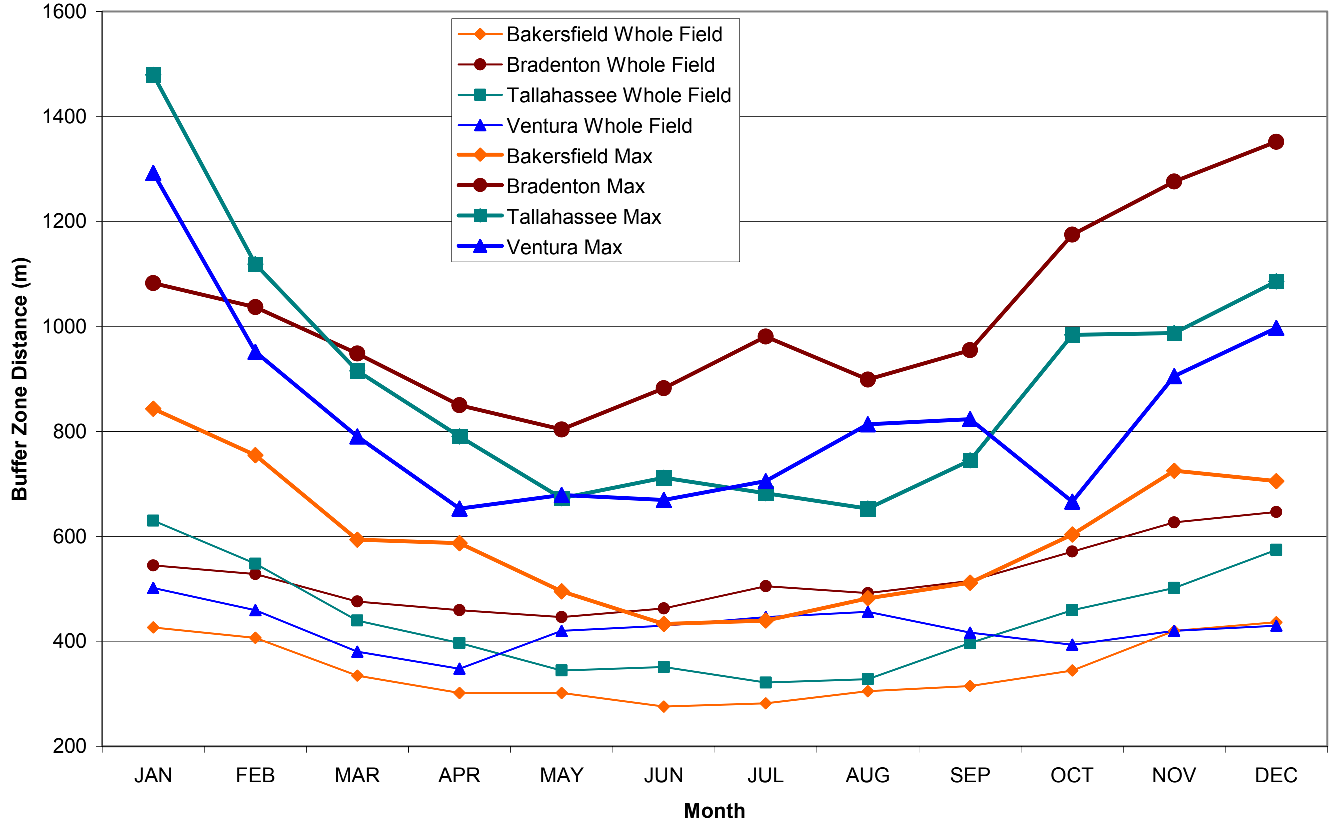


Figure 6.2. Buffer Lengths by Season for the PERFUM Approach and the Maximum Concentration Only Approach Using Flux Data from Manteca



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6.8 Summary of uncertainty analysis

Table 6.6 summarizes the uncertainty analysis. For each variable, the table includes a qualitative indicator of the direction of impact as follows: (↔): no reason to believe that the uncertainty in the variable biases the buffer estimates high or low, (↑) may bias the buffer estimates high, or (↓) may bias the buffer estimates low. For about half of the variables, there is no reason to believe that the uncertainty in the variable biases the results high or low. However, if more studies of the iodomethane flux were conducted, at least a few of the studies may yield higher flux rates, given the variability observed for methyl bromide.

There could be occasional impacts from applications of multiple fields in the same vicinity, which may result in higher concentrations than predicted in PERFUM. However, the probability of such impacts will be a function of the final buffer zone distances.

There are several variables where assumptions were made that likely result in overestimations of downwind concentrations in PERFUM. For example, buffer distances were generally lower in the warmer weather periods, where applications are more frequent. However, no adjustments were made to account for the seasonal variability of applications, mostly because in developing national buffer zones it is hard to generalize about the seasonal patterns. Additionally, indoor exposures may be lower for iodomethane, but all of the calculations assume ambient exposures.

Perhaps the largest uncertainty in the modeling is the assumption that individuals spend 24 hours in the period following application at the perimeter of the buffer zone. It is more likely that most individuals that spend any time at the perimeter do not spend all 24 hours there. The calculations in PERFUM assume that the individual is at the perimeter, and outdoors, for all 24 hours. It is difficult to develop probabilities for how long an individual may be at the perimeter; however, it is expected that most individuals will spend less than 24 hours at the perimeter.

Table 6.6. Summary of Major Uncertainties in the Modeling System

Variable	Discussion	Direction of Impact
Measurement error for the flux rates	The standard errors from the flux studies were relatively small compared to the flux estimates. The modeling analyses were conducted using the flux estimate as a probabilistic input varied by the standard error of the flux estimate. This input did not affect the results significantly.	↔
Environmental variance affect on flux rates	There are several factors that may affect flux rates between applications, such as the ambient temperature, soil temperature, and soil type. The extensive database of methyl bromide flux studies suggests that significant variability is possible. However, there is no reason to believe that the iodomethane flux data collected to date is biased high or low.	↔
Variance in meteorology	The variance in meteorology was investigated by running a subset of the modeling analyses with 15 different meteorological data sets from across California and Florida, including mostly agricultural areas. A subset of four stations was chosen for final analysis that represented the whole 15 stations adequately.	↔

Variable	Discussion	Direction of Impact
Accuracy of air dispersion model	Many users of air dispersion models have commented that the accuracy for predicting peak concentrations is about a factor of two. However, for this relatively simple example (a ground-level source, non-buoyant plume, and small downwind distance), the accuracy is likely much better. Also, by calculating the flux rates by a back-calculation using the model, the results are essentially calibrated to the model, which should further reduce the uncertainty.	↔
Calm winds	The ISCST3 model was run in regulatory mode, which does not produce concentration estimates for calm hours. Instead, the model skips the calm hours and calculates period averages from the remaining non-calm hours. The use of the calms processor has been found to produce adequate estimates for regulatory purposes for EPA, so it is not expected that the use of the calms processor results in underestimates of the concentrations.	↔
Indoor exposure	Although there are not data available on iodomethane indoor concentrations, it is expected that concentrations indoors would be less than outdoors. Given the typical individual spends about 90% of their time indoors, lower indoor concentrations may significantly lower the potential risks.	↑

Variable	Discussion	Direction of Impact
Multiple fields	There is some potential for applications to occur in multiple fields in the same general vicinity, which could result in higher concentrations than are estimated from a single field scenario. This issue will be more relevant for large buffer zones. However, it is difficult to quantify the likelihood or magnitude of these impacts.	↓
Time activity patterns	The model estimates assume that a person spends 24 hours at the perimeter of the buffer zone and is outdoors. While this may be true in unusual circumstances, the more likely situation is that a person will either move away from the area altogether for some portion of the 24 hours after an application, or will, at least, not spend the entire 24 hours at the perimeter. Of course, virtually all people spend some portion of a 24 hour period indoors.	↑
Seasonal variation in applications	The lowest buffer zones were generally found in the summer, and the highest in winter. Because applications in most areas are more likely to occur in the warmer weather periods, the assumption of an equal probability of application for any day of the year likely yields a conservative result.	↑

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