# Analysis of Weather Patterns in Lompoc, California

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## PURPOSE

The purpose of this evaluation was to determine if meteorological patterns in Lompoc differ from patterns in other coastal sites in ways that would be likely to increase the presence of pesticides in the air.

## BACKGROUND

Citizens in the city of Lompoc, Santa Barbara County, have brought their concerns about use of agricultural pesticides to the forefront. Beginning in late 1993, the Santa Barbara County Agricultural Commissioner's Office received written complaints from Lompoc residents about pesticide use near their town. Some residents have attributed health problems to pesticide use and have expressed concern about exposure to agricultural chemicals that they believe may be carried from fields as a result of local weather conditions. A constant concern raised by the community is that the local weather patterns (*i.e.*, wind, fog, inversions) may result in high exposure to pesticides. To address this concern, this study seeks to determine if residents in Lompoc might be more exposed to pesticides because of the local weather patterns. To accomplish this, a comparative evaluation of the weather patterns in the Lompoc Valley was conducted.

## STUDY METHODS

Weather stability data from two meteorological stations in and near the city of Lompoc[1] were compared to data from 11 California Irrigation Management Information System (CIMIS) meteorological stations located in coastal areas of California. These data included years 1992 to 1995. Stability classes are categories that indicate how much vertical mixing occurs in the air column. The stability classes range from A to F. Stability class A represents conditions of greatest vertical mixing (e.g., warm, sunny afternoons), and stability class F represents the least vertical mixing (e.g., pre-dawn, cold, still). The monthly average percentage of the F stability class was used as an index of conditions that might lead to higher air concentrations of pesticides, *e.g.*, higher percentages of F stability would indicate conditions for that month that might lead to higher air concentrations of pesticides.

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[1]The H Street station is located in downtown Lompoc at 105 feet above sea level; the HSP station is about six miles north northeast of the H Street station at 722 feet above sea level.

The Department of Pesticide Regulation (DPR) used the U.S. Environmental Protection Agency's Industrial Source Complex model (ISCST3) for computer simulations to evaluate if a statistically significant greater percentage of F stability conditions for a month might lead to higher-than-expected pesticide air concentrations. By making some assumptions about pesticide evaporation from a field (out-gassing rate or flux) and other factors, one can model what pesticide air concentrations might result under certain stability class conditions.

Wind speed was also analyzed, as was wind direction persistence.

## RESULTS AND CONCLUSIONS

Comparison of Lompoc to CIMIS stations–percentage of F stability: In the city of Lompoc, monthly percentages of F stability from the meteorological station in the city of Lompoc were not statistically different from the CIMIS stations, that is, there were about the same number of days with still weather. At the HSP station, about six miles north of the city of Lompoc, percentages of F stability were significantly higher for July, August, and September than the averages at the other CIMIS stations, that is, the air tended to be stiller than average.

Computer simulation: Since July was the month with the most stable air at the HSP station, those data were used in comparisons modeled in the computer simulations. These simulations estimated the effect of stable air conditions on air concentrations of chemicals, and integrated the effects of wind speed and direction. The results indicated that air concentrations within one mile of a 10-acre field might be up to 30 percent higher compared to the corresponding average from the 11 CIMIS stations. This increase is modest relative to sampling variability in air monitoring programs. This simulation did not include possible effects from drift, systematic differences between Lompoc stations and CIMIS stations in mixing height, terrain effects, or complex patterns of partial cloud cover which occur in the Lompoc Valley.

Analysis of wind direction persistence: At the H Street site, the dominant wind direction is from the west northwest, which brings the wind across major agricultural areas before reaching the city of Lompoc. The analysis indicated a high degree of persistence at the H Street site (especially March through October) compared to the 11 CIMIS stations. At the HSP station, dominant wind directions were more variable than at the H Street site, mostly coming out of the west, northwest, and north. The HSP station did not differ statistically from the CIMIS stations in this regard.

Analysis of wind speed: For the 11 CIMIS stations, wind speed was less than 4 miles per hour for 58.9 percent of the time. At the H Street station, wind speed was less than 4 miles per hour for 53.7 percent of the time; at the HSP site wind speed was less than 4 miles per hour 47.4 percent of the time. Wind speeds at the HSP site occurred more frequently in the 10 to 12 and 12 to 14 miles per hour classes than they did at the 11 CIMIS stations.

Conclusions: These findings, taken together, indicate that certain aspects of the meteorology in the Lompoc Valley are statistically different when compared to 11 coastal CIMIS meteorology stations in patterns that could lead to higher concentrations of pesticides in the air.

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## Measurement units used in report

| | |
|---|---|
| mph | miles per hour |
| km | kilometer |
| m/s | meters per second |
| m | meter |
| $ug/m^2s$ | micrograms per meter squared per second |
| s/m | seconds per meter |
| $ug/m^3$ | micrograms per meter cubed |

**Abstract**

Hourly weather stability from two meteorological stations in and near the city of Lompoc were compared on a monthly basis to 11 coastal California Irrigation Management Information System (CIMIS) meteorological stations. Data from all stations roughly encompassed 1992 to 1995. The monthly average percentage of F stability was used as an index of conditions which might lead to higher air concentrations of pesticides. Higher percentages of F stability would connote conditions which might lead to higher air concentrations of pesticides. Monthly percentages of F stability from the meteorological station in the City of Lompoc were not statistically different from the CIMIS stations. The same comparison between the HSP station, about 6 miles north of the City of Lompoc, indicated that there were statistically higher percentages of F stability during July, August and September. The CIMIS percentages of F stability were 27.8, 30.6, and 34.1 for July, August, and September, respectively. The corresponding percentages for the HSP station were 33.5, 36.1, and 38.7. These higher percentages amounted to approximately one extra hour per day of F stability.

Based on computer simulation with July weather, including wind speed and direction, 24 comparisons were made with scenarios of high mixing height and low mixing height and a variety of statistical measures. Six comparisons resulted in lower normalized pesticide concentrations for a Lompoc station, 16 comparisons were not statistically different, and two comparisons resulted in higher normalized pesticide concentrations for a Lompoc station. In the latter case, the 50$^{th}$ percentile of the distribution of mean normalized concentration of the H St. station in the City of Lompoc was 29% higher than the corresponding CIMIS station average for the high mixing height scenario. The 90$^{th}$ percentile of the distribution of mean normalized concentration of the HSP station was 32% higher than the corresponding average of the CIMIS stations in the low mixing height scenario. The simulations did not take into account drift, possible systematic differences in mixing height between Lompoc and CIMIS sites, complex cloud patterns, or terrain effects. The magnitude of the modeled effects was modest.

Analysis of the persistence of wind direction indicated a high degree of persistence at the H St. site compared to the 11 CIMIS stations. March through October frequencies were significantly greater than the corresponding CIMIS station frequencies. HSP did not differ significantly from the CIMIS stations in this regard. The wind direction for H St. was also very consistent, generally coming out of the west north west, which brings it across major agricultural areas before reaching the City of Lompoc.

These findings indicate that aspects of the meteorology in the Lompoc Valley are statistically different in comparison to 11 coastal CIMIS meteorology stations in patterns which could lead to higher concentrations of pesticides in the air.

## Introduction

The use of pesticides in agricultural areas close to urban dwellings is controversial as urban residents have become more concerned about pesticides in the air, soil, and water, and about the effectiveness of regulatory restrictions in protecting citizens from pesticide exposure.

Citizens in the city of Lompoc, Santa Barbara County, have brought their concerns about use of agricultural pesticides to the forefront. Since late 1993, the Santa Barbara County Agricultural Commissioner's Office has received written complaints from Lompoc residents about pesticide use near their town. They have attributed health problems to pesticide use and have expressed concern about exposure to agricultural chemicals which they believed may be carried from fields as a result of local weather conditions. A constant concern raised by the community is that the local weather patterns (*i.e.*, wind, fog, inversions) result in high exposure to pesticides. Air exposure to pesticides also depends on pesticide type and source strength. This study examines the possible effect of meteorology on potential pesticide air concentrations. This study seeks to determine whether residents in Lompoc might be more exposed to pesticides because of the local weather patterns. To accomplish this, a comparative evaluation of the weather patterns in the Lompoc Valley was conducted. The purpose of the evaluation was to determine if meteorological patterns in Lompoc differ from patterns in other coastal sites in ways which would be likely to increase the presence of pesticides in the air.

**Regional Climatology**. The Lompoc Valley is located near the coast in Santa Barbara County. The Valley itself is oriented roughly northwest to southeast (Figure 1). The City of Lompoc is at the east end of the Valley, approximately eight miles from the Pacific Ocean. Between the City and the Ocean is an agricultural area producing vegetables and flowers.

During the summer, the region is dominated by a Pacific high pressure area. This high pressure area tends to produce northwesterly winds in the Lompoc area. Aiding this tendency, the Central Valley of California heats up during the summer and creates a large pressure and temperature differential between inland and ocean surfaces. The air aloft from the Pacific High is generally warming and descending as it approaches the coastline near Vandenberg Air Force Base. Consequently, the cool moist marine area below tends to form a subsidence inversion accompanied by frequent fog or low cloudiness. The northwesterly winds exert pressure on the ocean surface which causes upwelling of cool water. This cools the air near the surface and contributes to fog formation. During winter, the Pacific high weakens, the jet stream shifts southward, and heating of the Central Valley is weaker or absent. Winds tend to be more westerly and frontal systems move through the area, changing the wind direction. Terrain exerts local effects. Such effects can be mechanical, such as blocking, lifting or channeling. Terrain can lead to upslope flows of heated air during the day or downslope flows of cold air at night. (Kamada et al. 1989, McClelland Consultants 1989).

## Methods

**Lompoc data.** Data were obtained from two meteorological stations in Lompoc from May 1, 1991 through April 30, 1995. The two stations were the H St. station located in downtown Lompoc on H St. between Ocean and Cypress Streets at 105 feet above sea level (Figure 1). The other was the HSP station located about 1.8 km NNE of the intersection of Harris Grade and Rucker Rd. at an elevation of 722 feet above sea level (Figure 1). The HSP station is about 6.3 miles NNE of the intersection of H St. and Ocean St. in downtown Lompoc. The data obtained consisted of date, hour of the day, vector wind speed, scalar wind speed, wind direction, and standard deviation of wind direction. CIMIS net radiation estimates from Santa Maria were used for determination of night and day. Santa Maria is on a similar longitude as Lompoc. The two Lompoc stations measure wind speed at 10 m above the ground surface. The minimum speed threshold is 0.22 m/s (0.49 mph), though as units age the threshold may increase to 0.5 m/s (1.12 mph) (Sikorski, personal communication).

**CIMIS data.** Data were obtained from 11 coastal CIMIS meteorological stations. These stations were selected using a map of CIMIS stations and selecting all 14 stations that were near the coastline (Figure 2). These included 16, 19, 49, 52, 64, 66, 67, 76, 94, 95, 96, 97, 102, 104. Date, hour of the day, vector wind speed, scalar wind speed, wind direction, standard deviation of wind direction and net radiation estimates were obtained for the period 1/1/92 through 12/31/95, which approximated the period for which Lompoc data was obtained. Stations 67, 76 and 96 were subsequently omitted due to insufficient data. CIMIS stations measure wind speed at 2 mheight above the ground. Stations are located in rural areas. The minimum wind speed threshold is 0.45 m/s (1.0 mph) (Department of Water Resources, 1998). In CIMIS stations net radiation is not measured directly. It is estimated based on an empirical methodology presented by Dong et al. (1988) (Eching, personal communication).

**Station locations and other data.** Table 1 lists the 11 CIMIS and two Lompoc meteorology stations with some additional information. The Lompoc stations were approximately in the middle range of the CIMIS station latitudes. For elevation, the H St. station was less than the average, while the HSP station was higher than any of the 11 CIMIS stations. With regard to distance from the ocean, both Lompoc stations were more inland than the majority of CIMIS stations.

**Computation of stability class**. Stability class determination was based on Pasquill stability categories using the wind direction standard deviation, whether it was night or day and the wind vector speed (Irwin 1980, USEPA 1986, Zannetti 1990). The complete algorithm can be found in the Appendix. In brief, the algorithm requires making an initial determination of stability based on the magnitude of the standard deviation in degrees of the wind direction. Greater than 22.5 was A, between 17.5 and 22.5 was B, between 12.5 and 17.5 was C, between 7.5 and 12.5 was D, between 3.8 and 7.5 was E and less than 3.8 was F. Day and night were determined by the sign of the net radiation estimates: a negative sign for night and positive sign for day. If the initial stability determination was during the day, then that became the final stability for that

hour. If the initial stability determination was during night, then for classes D, E, F, the stability was final. For class A, the stability was changed to F, E, and D, respectively with vector wind less than 2.9 m/s (6.5 mph), between 2.9 and 3.6 m/s (6.5 and 8.0 mph) or greater than 3.6 m/s (8.0 mph). For class B, the stability was changed to F, E, D, respectively for vector wind speed less than 2.4 m/s (5.4 mph), between 2.4 and 3.0 m/s (5.4 and 6.7 mph) or greater than 3.0 m/s (6.7 mph). For class C, stability was changed to E and D for vector wind less than 2.4 m/s (5.4 mph) or greater than 2.4 m/s (5.4 mph), respectively. Hour to hour stability class changes were restricted to no more than one class change per hour. That is, jumps of two or more stability classes between adjacent hours were not allowed.

Gildart (1977), in a comparison of several schemes for estimating stability, placed confidence in utilization of the standard deviation of horizontal wind condition as being reflective of general meteorological conditions. The methodology used in the current study to assess stability class is well known (Zannetti 1990). This methodology can underestimate stability under nighttime stable conditions when plume meander may increase the standard deviation of wind direction (Hanna 1983).

**Missing values.** Days with more than four missing hours in either wind speed, wind direction, standard deviation of wind direction, temperature or net radiation estimates were not used for stability determinations. That is, the entire day (hours 1-24) was omitted from stability calculations. When four hours or less were missing, interpolation from adjacent hours was used to replace those missing values. The incidence of usable and non-usable days is summarized in Table 2. The H St. station lacked sufficient information to calculate stability until May 21, 1992.

**Percentage of F stability.** The parameter used to gauge the incidence of stability was the percentage of F stability, that is, the proportion of hours which were classified as F stability. A higher percentage would represent a greater incidence of stable periods.

**Calculation of wind speed and direction.** Both the CIMIS and Lompoc stations use the same formulas for calculating wind speed and direction. The vector wind speed is calculated as the magnitude of the vector formed by the average of the x and y components of speed.

$$\bar{U} = (\bar{x}^2 + \bar{y}^2)^{\frac{1}{2}}$$
$$\bar{x} = \sum \frac{S_i \sin(\theta_i)}{N} \qquad \textbf{(1)}$$
$$\bar{y} = \sum \frac{S_i \cos(\theta_i)}{N}$$

where $\theta_i$ is the measured wind direction and $S_i$ is the corresponding measured wind speed. The

wind direction is based on the inverse tangent function of the ratio of the average wind direction components, weighted by speed, and with an appropriate adjustment of the angle by 180° depending on the specific arctan function and whether the numerator and denominator are positive or negative.

**Calculation of standard deviation**. The methods used internally by the data loggers to calculate the standard deviations of wind direction differ between the CIMIS system and the system used in Lompoc stations. The CIMIS system uses a formula based on a truncated Taylor series expansion for cosine (Campbell Scientific 1987). The derivation is provided in the Appendix. The formula is

$$\sigma(\theta) = 81(1-\frac{\bar{U}}{\bar{S}})^{\frac{1}{2}} \tag{2}$$

$$\theta = \arctan\left(\frac{\bar{x}}{\bar{y}}\right) \tag{3}$$

where

$$\bar{U} = (\bar{x}^2+\bar{y}^2)^{\frac{1}{2}}$$
$$\bar{S} = \sum \frac{S_i}{N} \tag{4}$$

with $\theta_i$ as the measured wind direction and $S_i$ as the corresponding measured wind speed. The factor of 81 results from converting radians to degrees (Campbell Scientific 1987). The truncated Taylor series expansion only applies to the CIMIS method for determining standard deviation, and not to computation of average wind direction. CIMIS stations record one instantaneous measurement every 60 seconds. Hourly summaries are based on the 60 measurements.

The method used by the data loggers in Lompoc, called the ESC method, is first to compute an average wind direction. Next each individual direction measurement is subtracted from the average direction and normalized to lie between -180 and 180 in order to avoid the wrap around problem which occurs near 360 degrees (which is also 0 degrees). Then the conventional standard deviation formula is used to find the standard deviation. This procedure is performed seven more times, using the average angle +45, average angle +90, average angle +135, etc. The smallest of these eight standard deviation estimates is used as the standard deviation (Hallerman 1997).

In symbolic form, the ESC method first adjusts individual measurements as

$$q_i = \left[\frac{\sum \theta_i}{N}\right] - \theta_i \qquad \textbf{(5)}$$

The $\theta_i$ are the individual angular measurements. Then the $q_i$ are normalized to lie between -180 and 180 degrees. The $q_i$ are used as follows to calculate the standard deviation with the conventional equation **(6)**. This procedure is repeated for each of the eight angular pseudo averages found by adding 0, 45, 90, etc. to the average in brackets in equation **(5)** above, followed by the application of equation **(6)**.

$$\sigma(\theta) = \sqrt{\frac{\sum q_i^2}{N} - \left(\frac{\sum q_i}{N}\right)^2} \qquad \textbf{(6)}$$

The two Lompoc stations record instantaneous data once per second. A standard deviation of wind direction is computed every 60 seconds and recorded. The hourly standard deviation is based on the average of the sixty 60-second standard deviations. To compare the CIMIS and ESC algorithms for computing standard deviation of wind direction, 1000 sets of random wind data consisting of 3600 wind speed and wind direction data pairs were generated. Wind speed was generated as a uniform distribution between 2 and 7 m/s (4.5 and 15.7 mph). Wind direction was simulated with a fixed mean wind direction of 180° and for each set of 3600, a randomly chosen standard deviation between 3° and 25° was chosen from a uniform distribution. Then a set of 3600 angles was constructed from a normal distribution with mean of 180° and standard deviation as previously chosen for that set. The two methods for calculation of standard deviation were used on each of the 1000 sets of 3600 simulated wind speed, wind direction data pairs. The CIMIS method was simulated using one sample from each minute and determining the hourly standard deviation based on the 60 samples using the Campbell Scientific algorithm. The ESC method was simulated by determining the standard deviation for each 60 seconds of data as described above, then taking the average of the sixty one-minute standard deviations to compute the hourly standard deviation. The results were analyzed by comparing regressions of the ESC and CIMIS methods to the true standard deviation. The regression equations relating CIMIS and ESC methods to 'true' standard deviation were used to adjust the CIMIS data standard deviations; in effect, to estimate the standard deviation as though the ESC algorithm had been used. The statistical analysis of the percentage of F stability was then rerun based on the adjusted standard deviations in the CIMIS files to determine if the biases in the different methods made a difference in the results of the statistical analysis of F stability.

**Statistical comparison by months.** For each of the 11 CIMIS stations, and for the two Lompoc stations, a percentage of F stability for each month was determined based on the total number of

usable hours for that month, over the years for which data were obtained. For the 11 CIMIS stations, a mean and standard deviation of the percentage of F stability were calculated. This mean and standard deviation were used to determine if either of the corresponding percentages from the two Lompoc stations were significantly different at the 5% significance level in a two-tailed test (Fleiss 1973, Snedecor and Cochran 1967). A t-distribution with 10 degrees of freedom was used in this determination. For each month the two Lompoc stations were each compared separately to the mean of the CIMIS stations because the two Lompoc stations represented the range of conditions in the Lompoc Valley (Sikorski, personal communication). Statistical comparison was done using both untransformed and arcsine square-root transformed data. The latter transformation is customary for fractional or percentage data (Little and Hills 1978).

**Adjustment of significance levels for experimentwise error rate.** Because the above procedure involved 24 comparisons, an adjustment to the individual test level was necessary to counteract inflation of Type I error, which results from multiple comparisons. When many comparisons are planned, the probability of falsely rejecting the null hypothesis increases. Therefore, the individual test criteria must be lowered in order to maintain an overall testing level of 5%. To calculate the value needed for this adjustment, equation 7 was solved. Equation 7 represents setting to 5% the probability of obtaining one or more successes (significant differences) by chance in 24 trials. When this equation was solved, the corresponding probability of an individual success was 0.213%. Therefore, an individual test level of 0.213% was used for determining whether a particular Lompoc station was significantly different from the average CIMIS station for a particular month. Another way to state these criteria is that the probability that strictly by chance there would be one or more significant test results out of 24 trials is 5% when the individual probability of success is 0.213%. Equation 7 expresses the concept of finding p, such that the probability of one or more successes occurring by chance is 5% or 0.05.

$$\begin{aligned} 0.05 &= Pr\{k \geq 1\} = 1 - Pr\{k=0\} = 1-(1-p)^{24} \\ p &= 0.00213 \end{aligned} \tag{7}$$

To achieve an experimentwise 5% confidence interval, an individual trial level of p=.00213, for a 2-sided test, would require finding the t-value (shown as q in the equation below) such that

$$.00213 = \int_{-\infty}^{-q} T_{10}(x)dx + \int_{q}^{\infty} T_{10}(x)dx \tag{8}$$

where $T_{10}$ is the t distribution with 10 degrees of freedom and q is the t value needed to satisfy the equation. Because the t distribution is symmetrical about zero, the equation for the value of q can be rewritten in a one-sided form, which is how most tables of t values are presented.

$$1 - \frac{.00213}{2} = \int_{-\infty}^{q} T_{10}(x)dx$$

$$0.99893 = \int_{-\infty}^{q} T_{10}(x)dx \qquad (9)$$

The value of q, which satisfies the equation is 4.10.

**Computer simulation to interpret implication of statistical significance of different fraction of F stability for July weather.** If the stability index analysis indicated that there was a statistically significant greater fraction of F stability in either of the Lompoc stations compared to CIMIS stations, then a simulation would be conducted to gauge the size of that difference in terms of normalized air concentrations in a comparison among the 11 CIMIS stations and the Lompoc stations. The month with the maximum difference between the average CIMIS station value and the Lompoc station value would be determined. The simulation would utilize a 10-acre field. For each CIMIS station, and for each Lompoc station, the weather for the selected month from all years in the data set would be used for the simulation. A generic flux of 1 ug/m$^2$s would be assumed in order to provide normalized concentrations in units of s/m. The term flux is equivalent to efflux or emissions and represents the movement of mass from the soil or plant surface into the atmosphere per unit area per unit time. The normalized air concentration units were derived as follows:

$$\frac{C}{F} = \frac{\frac{\mu g}{m^3}}{1\frac{\mu g}{m^2 s}} = \frac{s}{m} \qquad (10)$$

where C is concentration and F is flux at 1 $\mu g m^{-2} s^{-1}$. A 10-acre field is equal to 201x201 m. The simulation would utilize a 200x200 m field. A grid of receptors on a 200 m spacing centered on the field and extending 1600 m (approximately 1 mile) would be placed around the field. This would result in an 18x18=324 point grid, roughly four square miles, centered on the field. The grid lines at x=1600,1800 and y=1600,1800 would be shifted away from the field to x=1599, 1801 and y=1599, 1801 in order to avoid any potential problems with receptors located on the field. The model utilized for these calculations would be the USEPA model, ISCST3, which is a Gaussian dispersion model (USEPA 1995a,b). The fundamental equation utilized in this model employs numerical line integration over area sources to evaluate the following equation:

$$C = \frac{FK}{2\pi U_s} \int_x \frac{VD}{\sigma_y \sigma_z} \left( \int_y \exp\left[ -0.5 \left( \frac{y}{\sigma_y} \right)^2 \right] dy \right) dx \qquad \textbf{(11)}$$

where C is air concentration (ug/m$^3$), F is flux or area source emission rate (ug/m$^2$s), K is a units scaling coefficient, V is the vertical term, D is the decay term, $\sigma_y$,$\sigma_z$ are empirically estimated horizontal and vertical dispersion terms (m), Us is wind speed (m/s), x is downwind distance (m), y is cross wind distance (m), z is height (m). This equation is from USEPA (1995b), equation 1-65 on p.1-47. It can be seen from the equation that flux, F, and concentration, C, are linearly related to one another. Therefore, doubling the flux results in doubling the air concentration. This is the justification for using normalized air concentrations as described in equation 10 above. Simulations would use ISCST3 in conjunction with the fixed geometry described above and would be run utilizing meteorological files from each of the 11 CIMIS stations and each of the two Lompoc stations for the targeted month weather.

To gauge the possible effect of low and high mixing heights, the simulations would be run twice: once with a mixing height of 300 m to represent afternoon conditions and once with a mixing height of 10 m to represent low mixing heights during early morning hours. For each simulation, the following data would be produced: highest 24-hour average normalized concentration, second highest 24-hour average normalized concentration and average normalized concentration during the entire month. These endpoints were chosen to sample from approximate medium and short term exposures, where short term exposure corresponds to the highest and second highest 24-hour average concentration over the period and a medium exposure corresponds to the average exposure over the time period of one month. For each station at each mixing height and each output data type, the resulting normalized concentrations would be ranked, arrayed as a cumulative histogram and the 50$^{th}$ and 90$^{th}$ percentiles would be determined. The CIMIS stations results would be averaged and corresponding data types from the two Lompoc stations would be compared to the average CIMIS station data type. This comparison scheme would result in 2 percentiles x 2 Lompoc stations x 3 data types x 2 mixing heights=24 comparisons. This is the same number of comparisons as in the stability comparison test. Therefore, the same experimentwise error scheme would be utilized with individual success levels set at 0.213% by using a $t_{10}$ value of 4.10.

**Use report data.** Use report data from 1991 through 1994 was summarized for 5 sections, S07N34W27, S07N34W28, S07N34W29, S07N34W32, S06N34W05 which were identified in Akers et al. (1995) as agricultural urban interface (AUI) sections in Lompoc. Application frequency, both ground and aerial, was summarized by month.

**Wind persistence analysis.** The constancy of wind direction was assessed for the HSP and H St. stations in comparison to the 11 CIMIS stations. For each station for each month, the following procedure was utilized. The hourly wind directions were tabulated into 45° progressively located frequency distributions. The basis for each frequency distribution was

dividing the 360 range of possible directions into eight equal intervals. The first iteration used intervals, which in degrees, ranged from 0-45, 45-90, ...315-360. The frequency distribution was formed. The maximum interval was recorded. Next the intervals were shifted by 1 degree: 1-46, 46-91, ... 315-361. Then the frequencies were again tabulated. If the maximum frequency from this tabulation exceeded the previous maximum, it was recorded; otherwise the original maximum frequency was retained. This procedure continued until boundaries for the first interval reached 44-89 degrees, the second 89-134 degrees, etc. The result of this procedure was a 45 degree sector bracketing the highest frequency. The reason for utilizing this maximization procedure was to avoid finding a maximum which was highly dependent on the particular interval ranges, which could split the peak frequency if the peak frequency zone happen to occur on a multiple of 45 degrees.

After determining the frequency for the maximum for each station for each month, the maximum frequency for each of the two Lompoc stations was compared to the average CIMIS maximum frequency, month by month. Statistical adjustment for the experimentwise error rate was utilized, as previously discussed.

**Wind speed analysis.** Annual scalar wind speed frequencies in 2 mph (0.9 m/s) intervals for the H St. and HSP stations were compared to corresponding measurements for the 11 CIMIS stations. Due to the small numbers in intervals greater than 16 mph (7.2 m/s), only the first eight intervals were statistically compared. This comparison required an experimentwise error adjustment similar to the previous adjustment except that the exponent in equation 7 was 16 (=2x8), instead of 24. The corresponding 1-sided $t_{10}$ value was 3.85234 in order to achieve an experimentwise error rate of 5%.

## Results

**Comparison of Lompoc to CIMIS stations: percentage of F stability.** The monthly comparison between the average of the 11 CIMIS stations and the two Lompoc stations is shown in Figure 3 and Table 3. Three of the 24 comparisons were significant and 21 were not significant. No months from the Lompoc stations exhibited significantly lower F stability percentages than the CIMIS stations. The HSP site exhibited significantly higher percentages of F stability in July, August and September. The arcsine square root transformation had only negligible effect on significance levels in all cases. All stations exhibited a seasonal pattern of higher F stability in winter than in summer; hence, the U-shaped curves in Figure 3. This pattern occurs in part because during winter the night time periods are longer and F stability occurs with greater frequency during night time. Though not quantified statistically, the Lompoc stations appeared to exhibit a seasonal pattern in relation to each other, with the HSP showing higher F stability in summer than H St. and the reverse in winter.

A seasonal trend also appeared to occur with respect to the variances (presented as standard deviations in Table 3) of the 11 CIMIS stations. The variances reach a minimum in summer and a maximum in winter. Levene's test for equal variance confirms that these variances were

statistically different ($F_{11,120}$=3.70, p<0.001). Repeating the variance analysis under the arcsine square root transform had negligible effect.

**Impact of bias in different wind direction standard deviation algorithms.** CIMIS and Lompoc data loggers employ different algorithms and sampling frequency for computing standard deviation of wind direction. It was necessary to examine the possibility of bias in the mean values. The results of the simulation analysis indicated that the ESC algorithm slightly underestimated the 'true' standard deviation of wind direction (y=0.985x, $r^2$=99.9%, p<0.001). The CIMIS algorithm showed slight overestimation at the smaller standard deviations (<5°), and a small underestimation at the higher standard deviations (y=0.955x+0.222, $r^2$=94.9, p<0.001)(Figure 4). The CIMIS regression was solved for x, representing the true standard deviation. Then this equation was multiplied by 0.985 to obtain a corresponding ESC value. This transformation was used to adjust the CIMIS standard deviations to their equivalent value had they been calculated using the ESC procedure. The resulting combined equation was $y_{ESC}=(0.985)((y_{CIMIS}-0.222)/0.955)=1.03y_{CIMIS}-0.23$. This equation was applied to each standard deviation value in the CIMIS data set and the results were reanalyzed and compared to the Lompoc data.

The original percentages of F stability were slightly increased by the transformation of the standard deviations (Figure 5). The largest change represented about 0.7% relative increase over the original value. Using these percentages of F stability based on the transformed standard deviations, there were only trivial changes in the statistical analysis which compared the CIMIS values to the Lompoc values. In summary, the impact of the different techniques for estimating the standard deviation of the wind direction had no important effect on the CIMIS mean percentages of F stability or on the statistical comparison of CIMIS to Lompoc mean percentage of F stability.

**Computer simulation to interpret statistical significance of different fraction of F stability.** July was the month with the highest difference between the HSP fraction of F stability hours versus the average CIMIS fraction of stability hours (Table 3). The high-mixing height results indicated that the H St. station was either non-significantly different or lower for each of the six comparisons to the average CIMIS data (Table 4). The HSP station was not significantly different in five comparisons. However, the HSP station was statistically significantly higher in the category of the 50$^{th}$ percentile of the mean concentration. In this case, the average for the HSP station was 0.09 s/m compared to 0.07 s/m for the CIMIS stations, a difference of 29%.

For the low mixing height comparison, the H St. station was not significantly different in two cases, significantly lower in three cases and significantly higher in the 90$^{th}$ percentile of the mean values. The H St. 90$^{th}$ percentile was 0.97 s/m compared to the average CIMIS value of 0.73 s/m, a difference of 32% (Table 4). The HSP site was not significantly different from the average of the CIMIS stations in any of the six comparisons for the low mixing height case.

Figure 6 provides a contour graph of the 11 CIMIS stations and the HSP station for the mean

concentrations under the high mixing height simulations. The contour intervals were chosen to emphasize the 50th to 90th percentile range, which for the CIMIS stations averaged 0.07 s/m and 0.32 s/m, respectively. In terms of the individual graphs shown in Figure 6, the 50th percentile should approximate an area within each plot which comprises about half of the area of the square. For example, for station 016, the 50th percentile was 0.07 s/m and the 0.07 contour line divides the area of the graph into two approximately equal areas. On the specific graph in Figure 6 for station 016, there are two separate 0.07 contour lines, trending roughly east-west. The area between those two lines and bounded by the edge of the graph is about ½ of the total graph area.

The interaction between the wind direction, the stability classes, and the resulting contours is complex and difficult to generalize. Amongst the CIMIS stations in the high mixing height scenario for mean values, the lowest 50th percentile was station 94 with 0.05 s/m (Table 4), which appeared to exhibit a stronger wind directionality than the other CIMIS stations, resulting in a longer, thinner ridge of concentration and large surrounding areas of lower concentration. The higher 50th percentile stations, 66, 102 and 104, exhibited much less wind directionality and more convoluted contours. This latter pattern was also exhibited by the HSP station.

Figure 7 provides the contour graphs of the 11 CIMIS stations and the H St. station for the mean concentrations at the low mixing height. For the 50th percentile amongst the CIMIS stations, the lowest values were with station 19 and 64 (Table 4), both of which probably exhibit greater wind directionality than most of the other stations, with the possible exception of 97 which also exhibits directionality and is low for the 50th percentile. The high CIMIS station for the 50th percentile was 104, which exhibited a convoluted and much less directional pattern. Station 94, which also exhibits this kind of pattern, was also high. The H St. station was significantly lower for the 50th percentile of average concentrations and consistent with CIMIS stations 19 an 64, exhibited a high degree of directionality. For the 90th percentile, station 19 was still the lowest CIMIS station, whereas station 64, which exhibited one of the lowest 50th percentile values, now exhibited the highest 90th percentile value. Comparing stations 19 and 64, while the strength of the wind directionality is similar, the higher concentration isopleths in the center push farther to the right for station 64. This extension of the higher isopleths also appears to be true for the H St. station, which shows high wind directionality and pushing of the higher isopleths in the center to the right (eastward).

In summary, one may make some generalizations. For the 50th percentile statistics of mean values under both the high mixing and low mixing height scenario, higher 50th percentiles resulted when there was less directionality and more convoluted shapes, such as the HSP result. Low values at the 50th percentile of the mean resulted from strongly directional flows. For the 90th percentile statistics of mean concentration, directionality and size of the center high isopleths appear to be important, but the totality of relationships did not seem as visually clear cut as in the 50th percentile case. The higher 90th percentile statistic for the H St. station appeared to be related to a larger center area which was extended eastward due to a strong wind directionality. For the short term normalized concentration measures (highest and second highest 24 hour average), both Lompoc stations were either not different from, or significantly lower, than the

average of the CIMIS stations. This analysis suggests that for this aspect of meteorology, differences between Lompoc and other coastal stations which might lead to higher air concentrations reside primarily in weekly or longer term averages, not in short term (24-hour) peak averages.

**Pesticide Use Report Data.** Tables 5a and 5b summarize the pesticide use report data for 1991 through 1994 for aerial and ground applications in the five AUI sections. Aerial and ground applications averaged 232 and 1861 per year, respectively, for the five sections. When viewed on a monthly basis, both aerial and ground application frequency peaked near the middle of the year (Table 5 and Figures 8, 9). Aerial applications peaked a month sooner than ground applications, with March and May being the two highest months. For ground applications, April and June were highest, followed by July, August and September, before application rate tailed off in October. The noticeably larger standard deviation in March and October ground applications probably reflects the year-to-year uncertainty in weather and ability to make ground applications during these transitional periods. For aerial applications, the four-month period from March to June comprised 53% of the yearly applications. For ground applications, the six-month period from April to September comprised 73% of the yearly applications.

Table 6 summarizes the actual statistical differences between the months based on Tukey's test for multiple means (Dixon 1992). For aerial applications, March and May percentages were actually only significantly greater than January, September and October percentages. The remaining months blurred together statistically. For ground applications, a clean separation occurred between the low months of January, February, November and December versus the higher application period of April through September.

**Wind direction persistence analysis.** Figure 10 summarizes wind directions for the entire data set in relation to the AUI sections. For the H St. station, the dominant wind direction ranged from 270-315 degrees, which is west to northwest, more or less parallel to the Lompoc Valley. For the HSP site, dominant wind directions were more variable, mostly coming out of the west, northwest, and north.

Results from the wind direction persistence analysis were consistent with the overall summary of wind direction for each station. The average maximum frequency for the 11 CIMIS stations ranged from 0.27 to 0.40 (Table 7). No monthly frequencies for the HSP station were significantly different from the CIMIS averages. However, for the H St. station, eight of the 12 months exhibited significantly greater persistence of wind direction than did the average CIMIS station. From March through October, the H St. station exhibited frequencies from 0.43 in March to a maximum of 0.76 in July. The midpoint of the 45 degree interval for the eight statistically significant months was remarkably constant ranging from 282 to 287 degrees, and averaging 284.5 degrees. Therefore, a 45 degree sector from 262 degrees (almost due west) to 307 degrees (almost northwest) encompassed a majority of the wind directions during that eight month period for the H St. site. The remaining 4 months, which were not significantly different

from CIMIS stations, also showed wind directions in the most frequent 45 degree sector ranging from 272.5 to 281.5, consistent with the other 8 months.

The wind directions of the highest 45 degree sectors for the HSP station were not as consistent as the H St. directions. The midpoints in degrees of the maximum 45 degree frequencies from January through December for HSP were 9.5, 8.5, 11.5, 302.5, 276.5, 261.5, 260.5, 261.5, 258.5, 8.5, 10.5, 9.5, respectively. These midpoints indicate a dominance of winds roughly from the west for May through October and a dominance of winds from the north during the remainder of the year.

**Wind speed analysis.** For the 11 CIMIS stations, on average, 58.9% of the hours indicated a wind speed less than 4 mph (1.8 m/s) (Table 8). The largest frequency occurred in the 2-4 mph (0.9-1.8 m/s) class with 35.6% frequency. Hourly wind speeds above 16 mph (7.2 m/s) were infrequent. The H St. station was similar to the overall CIMIS frequencies, with the exception of the 2-4 mph class, where the H St. station exhibited a significantly lower frequency of 25.1%, compared to the mean CIMIS frequency of 35.6%. The HSP station exhibited significantly lower frequency in the 0-2 mph (0-0.9 m/s) class and significantly higher frequencies in the higher speed classes from 10-12 (4.5-5.4 m/s) and 12-14 (5.4-6.5 m/s) than the CIMIS stations. While the t-test is reasonable to apply midrange, at the more extreme frequencies, there is some distortion in relation to the physical situation since the negative values for the lower end of the confidence intervals are not physically possible. To further check on the results for these more extreme frequencies, the arcsine-square root transformation was applied to the frequencies in the 10-12, 12-14 and 14-16 (6.3-7.2 m/s) intervals. This transformation did not change the results of the untransformed statistical analysis.

A more qualitative comparison between the two Lompoc stations was obtained by comparing the monthly frequency distributions for the H St. and HSP stations (Table 9). In the 0-2 mph category, the two stations exhibit nearly opposite trends. The H St. station averaged 28.6%, compared to the HSP station at 11.1% over 12 months. However, the H St. station had higher frequencies in this low wind speed category during the winter and lower frequencies roughly during the summer. The HSP station, on the other hand, had lower frequencies in this low wind category during the winter and higher frequencies during the summer and fall.

Both stations indicated higher wind speeds in spring. In the 8-10 and 10-12 mph categories, frequencies increased from about March to June.

## Discussion

The HSP station exhibited higher percentage of F stability during July, August and September than the average percentage based on the 11 CIMIS stations. This finding is consistent with the hypothesis that the meteorology in the Lompoc Valley is unusual in some way which might lead to higher air concentrations of off-gassing pesticides in July, August and September. However, the importance of these results should not be over interpreted. The largest difference between the

mean CIMIS value and HSP value occurred in July and was 5.7%. On a weekly basis in July, the number of F stability hours for the average CIMIS station was 47 and for the HSP station was 56, a little more than one extra hour of F stability each day.

The impact of that stability difference on the air concentration from an outgassing pesticide was gauged by a comparative simulation between the 11 CIMIS stations and the two Lompoc stations for July meteorological data. Regardless of mixing height maximum and second maximum 24-hour normalized air concentrations for both Lompoc stations exhibited concentrations which were either not different from or statistically significantly lower than the CIMIS stations. Of the eight comparisons for high or low mixing heights and highest or second highest normalized pesticide concentration, the H St. station was statistically significantly lower than the CIMIS stations on all four 50$^{th}$ percentile comparisons. For average concentrations, however, there was some indication of elevated levels in the Lompoc stations, on the order of about 30% higher. In relation to typical air monitoring sampling variability, 30% is a modest difference (See Appendix 5). The lack of statistical significance in the maximum and second maximum categories and the modestly greater difference in some of the mean statistic suggests that relevant time steps for any monitoring program that intended to target outgassing from fields (as opposed to drift) would be weeks or longer.

The comparative estimates obtained from the simulation must be tempered with consideration of what the simulations fail to account for. The meteorology in the Lompoc Valley is complex. A typical clear day 24-hour simulation, particularly during summer, will cycle through most of the stability classes. A cloudy day, however, may remain at D stability for hours. An unfortunate aspect of both the Lompoc and CIMIS meteorological data is that cloud cover is not recorded. Cloudy and sunny zones were specifically included in modeling a tracer gas release, Lompoc Valley Diffusion Experiment (LVDE), conducted during normal, day time "sea breeze" conditions in the period August 10-17, 1989 (Skupniewicz et al. 1990, Skupniewicz 1994). The release sites (generally at the mouth of Lompoc Valley) were usually cloudy, while downwind in the city of Lompoc, conditions were sunny. Skupniewicz (1994) discussed utilizing models which incorporated both overcast and clear sky parameters to explain results of the LVDE. In contrast, the meteorological data used in the simulations for Lompoc only reflect the point meteorology at the station.

Terrain effects also may complicate the meteorology. Localized daytime upslope flow or nighttime downslope cold air drainage from side canyons may complicate the pattern of airflow. Skupniewicz (1994), in analyzing the LVDE, discussed up-canyon flow as causing an enhanced spreading out of the plume such that off centerline concentrations were higher than expected, though centerline concentrations were comparable to those predicted by Gaussian modeling. The simulations conducted in this report also do not take into account any systematic mixing height differences which may exist between Lompoc and the CIMIS stations. Mixing heights are not part of the historical meteorological record in which Lompoc and the CIMIS stations can be compared. A glance at Table 4, for example, shows the magnitude of possible effect on the simulation of varying mixing heights. Under average 50$^{th}$ and 90$^{th}$ percentiles for mean

normalized concentrations at the CIMIS stations, the low mixing height averages are a little more than double the corresponding high mixing height averages. With systematic mixing height differences between Lompoc and other coastal areas, the potential exists for comparisons to be shifted up or down. Finally, the simulations in this report do not take into account drift. The process of drift requires a different kind of model. Such a model reflecting work of the Spray Drift Task Force is currently under development by the U.S. EPA.

In contrast to the HSP site, the lack of significant differences between percentage of F stability in CIMIS average and the H St. site may indicate a heat island effect at the H St. site. DeMarrais and Taft (1960) found that the range of stability conditions over an urban area was smaller than over open country and attributed this difference to the heat island effect of the city of Louisville, Kentucky. Though smaller, the City of Lompoc may create a local effect, which does not accurately reflect conditions in more rural areas of the Valley. In addition, the H St. station may exhibit lower wind speeds due to the higher surface roughness caused by surrounding buildings. However, lower wind speeds would generally be associated with higher frequency of stable conditions and no significant differences were found between the H St. station and the CIMIS stations for frequency of F stability. A possible explanation is that the CIMIS stations measure wind speed at 2 m height, whereas the Lompoc stations measured wind speed at 10 m height. In general, wind speed increases according to the well known log-wind speed profile (Rosenberg 1974). Consequently, the CIMIS stations might be biased towards lower wind speeds, which would bias them towards higher frequency of stable conditions. This possibility was investigated and it was determined that there was no effect on the statistical analysis (see Appendix, question B3 and response).

A tenet of this study has been that the two stations represent the range of conditions in the Lompoc Valley. The standard deviation of wind direction is the primary determinant of stability class in the algorithm employed in this work. Standard deviation of wind direction is a second moment statistical measure, which makes it more difficult to relate to more basic measures such as wind speed. For this reason, it is difficult to argue that historical record of standard deviations at one Lompoc station is more representative of typical valley conditions than the other. To be conservative, the results for the HSP station must be viewed as possibly applying to large areas within the valley.

Both the wind persistence and wind speed analysis tended to highlight differences between the HSP and H St. stations. Whereas wind persistence for the HSP station did not differ from the CIMIS stations, the H St. station exhibited a high degree of persistence compared to the CIMIS stations. The most frequent wind direction exhibited by the H St. station was from west north west, across major agricultural areas in the valley from March through October, which coincides with peak ground application months and overlaps with the March through August peak aerial application months. Local air pollution control district personnel describe the H St. and HSP stations as encompassing the range of conditions in the Lompoc Valley (Sikorski, personal communication). Both stations show a dominance of wind direction from west and northwest during May through October. In the remaining months, however, the HSP station showed a

dominance of winds from the north, while the H St. station continued showing winds from the northwest. It is conceivable that wind directions for the H St. station are influenced by the presence of nearby buildings. It is equally conceivable that local topography influences the HSP station. However, a seven year summary (1979-1985) of wind directions from a 54 foot tower located along the coast about 8 km north of the Lompoc Valley is more similar to the H St. meteorology, showing the same general pattern of dominant wind direction from the northwest (Kamada et al. 1989, Appendix A, Figure B3, Tower 102.) Because of this similarity and to be conservative, the general pattern of persistence in wind directions at the H St. site must be regarded as applying to large areas throughout the valley.

The general patterns of wind speed in relation to the CIMIS stations show mainly that the HSP site is windier, on average than the CIMIS stations. With regard to potential impact on air concentrations of pesticides fluxing from a field, more wind generally decreases air concentrations because the wind speed appears in the denominator of the concentration equation under the Gaussian plume formulation. In practical terms, more wind dilutes the presence of pollutants. The HSP site showed elevated frequencies in the 10-14 mph (4.5-6.3 m/s) wind speed categories from April to August, which encompasses much of the peak application months. Similarly, the H St. site showed elevated frequencies in the 8-10 mph (3.6-4.5 m/s) range from March through August. The wind speed may also influence estimated air concentrations through the mechanics of determining stability class. During night, lower windspeeds lead to estimation of more stable conditions and therefore, higher air concentrations. The computer simulations run for July attempted to integrate some of these opposing factors to quantify the two Lompoc stations in relation to the average CIMIS station. The maximum increase in any normalized concentration statistic of either Lompoc station over the CIMIS stations average was 32%. In relation to uncertainties in chemical analysis and toxicological and exposure assessments, this is not a large increase.

With regard to drift, the U.S. EPA interim guideline advises making aerial applications when wind speeds are between 2 and 10 mph (0.9-4.5 m/s). The high end of the range evidently is intended to reduce immediate, off-site drift near the application site. At longer distances, the increased wind dilutes air concentrations, just as in the case of outgassing from a field. Avoiding application at the lower end of the range is probably intended to reduce drift from smaller particles which occurs during stable or inversion conditions and can occur over longer distances than the downfield drift from high winds. In terms of modeling, F stability connotes inversion conditions and the HSP station exhibited greater F stability frequency than the average CIMIS stations. Whether the higher frequency of F stability exhibited by the HSP site or the higher frequency of 0-2 mph (0-0.8 m/s) wind speeds exhibited by the H St. site is more representative of the Lompoc Valley is unknown. In either case, however, relatively more drift could result.

Bird et. al. (1996) concluded that the primary determinant of downwind drift was droplet size. They review previous studies showing a variety of sometimes conflicting results ranging from stability having no effect on drift to more stable conditions leading to greater drift. They conclude that "Previous studies indicate stability effects are most significant 90 m and farther

downwind from the application area, potentially increasing deposition 13-fold when conditions change from unstable to very stable." (p.1104). For this reason some effort has been made to address the issue of pesticide application during very stable conditions for specific pesticides in specific locations (Department of Pesticide Regulation, 1995). However, the on-site, real-time determination and definition of stable conditions is difficult.

## Summary

Historical meteorological data from two Lompoc stations were compared to similar data from 11 coastal CIMIS stations. The HSP station exhibited higher fraction of F stability levels during July, August and September than the CIMIS stations. The H St. station did not different statistically from the CIMIS stations in this regard. A simulation to estimate the effect on air concentrations of pesticides for higher F stability and the integrated effects of wind speed and direction indicated that $50^{th}$ or $90^{th}$ percentile of monthly average air concentrations within 1 mile of a 10-acre field might be increased up to 30% compared to the corresponding average from the 11 CIMIS staions. This increase is relatively modest compared to various uncertainties which would be part of any monitoring and assessment program. This simulation did not include possible effects from drift, systematic differences between Lompoc stations and CIMIS stations in mixing height, terrain effects or complex patterns of partial cloud cover which occur in the Lompoc Valley.

Persistence of wind direction was pronounced at the H St. site with 8 months of maximum frequency wind direction being significantly greater than the corresponding average frequency from the 11 CIMIS stations. The HSP station was not significantly different than the CIMIS stations for wind persistence. The direction from which the wind blew at the H St site was also notably uniform, generally coming from the west north west, across major agricultural areas in the Lompoc Valley.

The statistical analysis indicates patterns of meteorology in Lompoc that when compared to the 11 coastal CIMIS stations could lead to higher concentrations of pesticides in the air, either from drift or outgassing following application.

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Table 1. Some characteristics of 11 CIMIS stations and two Lompoc stations.

| CIMIS Station | Decimal Latitude | Decimal Longitude | Elev. (feet) | Dist to Ocean (Miles) | Nearest City | County |
|---|---|---|---|---|---|---|
| 16 | 36.905 | 121.703 | 44 | 6.8 | Watsonville | Monterey |
| 19 | 36.768 | 121.774 | 9 | 1.6 | Castroville | Monterey |
| 49 | 33.256 | 117.32 | 50 | 5.3 | Oceanside | San Diego |
| 52 | 35.306 | 120.66 | 330 | 9.6 | San Luis Obispo | San Luis Obispo |
| 64 | 34.583 | 120.078 | 490 | 8.2 | SantaYnez | Santa Barbara |
| 66 | 32.733 | 117.135 | 370 | 2.5 | San Diego | San Diego |
| 94 | 34.472 | 119.868 | 640 | 3.6 | Goleta | Santa Barbara |
| 95 | 36.886 | 121.809 | 100 | 0.9 | Watsonville | Santa Cruz |
| 97 | 34.173 | 119.2 | 18 | 2.3 | Port Hueneme | Ventura |
| 102 | 33.797 | 118.094 | 17 | 3.7 | Long Beach | Los Angeles |
| 104 | 36.998 | 121.996 | 85 | 2.8 | Santa Cruz | Santa Cruz |
| **Avg** | 35.08 | 119.967 | 196 | 4.3 | | |
| | | | | | | |
| Lompoc | | | | | | |
| H St. | 34.638 | 120.457 | 105 | 8.4 | Lompoc | Santa Barbara |
| HSP | 34.726 | 120.428 | 722 | 10.2 | Lompoc | Santa Barbara |

Table 2. Usable and non-usable days for 11 CIMIS stations and two Lompoc stations for the stability class analysis.

| Station | Usable Days | Non-usable days | Total |
|---|---|---|---|
| 16 | 1009 | 323 | 1332 |
| 19 | 1387 | 74 | 1461 |
| 49 | 1069 | 26 | 1095 |
| 52 | 1452 | 9 | 1461 |
| 64 | 1412 | 49 | 1461 |
| 66 | 1375 | 86 | 1461 |
| 94 | 1432 | 29 | 1461 |
| 95 | 808 | 493 | 1301 |
| 97 | 1430 | 31 | 1461 |
| 102 | 1141 | 320 | 1461 |
| 104 | 931 | 464 | 1395 |
| | | | |
| H St. | 1031 | 430 | 1461 |
| HSP | 1311 | 150 | 1461 |

Table 3. Summary percentage of F stability statistics for 11 CIMIS coastal stations and H St. and HSP stations in Lompoc. Each entry is the percentage of hours classified as F stability. S.E.M. is the standard error of the mean. L(0.9989) and U(0.9989) refer to the lower and upper bounds of a 99.89% confidence interval calculated by average ± S.E.M.*4.10. The value of 4.10 represents a two-tailed 99.89% confidence value for the t distribution with 10 degrees of freedom, which is the confidence value required to produce a 95% experimentwise confidence interval with 24 comparisons. The mean percentage for HSP for July, August, and September were significantly higher than the mean percentages for the CIMIS stations. The remaining comparisons were not significant

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **16** | 21.3 | 28.9 | 28.9 | 30.6 | 27.2 | 27.2 | 30.0 | 33.7 | 39.8 | 41.7 | 33.4 | 25.2 | 29.6 |
| **19** | 22.8 | 24.7 | 26.5 | 23.2 | 17.7 | 17.4 | 22.5 | 27.4 | 32.2 | 38.2 | 33.2 | 31.1 | 26.4 |
| **49** | 45.7 | 41.9 | 38.4 | 35.0 | 31.8 | 28.1 | 30.6 | 31.9 | 34.6 | 41.2 | 46.1 | 51.3 | 38.0 |
| **52** | 47.6 | 43.3 | 39.8 | 32.1 | 31.6 | 27.8 | 29.3 | 32.8 | 36.1 | 40.4 | 44.3 | 49.3 | 37.9 |
| **64** | 47.7 | 41.9 | 39.9 | 35.6 | 33.9 | 30.4 | 30.6 | 33.1 | 37.3 | 44.9 | 48.1 | 51.8 | 39.6 |
| **66** | 35.8 | 32.2 | 27.0 | 27.3 | 29.1 | 27.7 | 30.1 | 33.4 | 32.3 | 33.8 | 35.7 | 37.5 | 31.8 |
| **94** | 38.8 | 36.8 | 33.4 | 28.3 | 28.3 | 24.1 | 26.1 | 27.7 | 31.1 | 37.9 | 42.3 | 43.6 | 33.1 |
| **95** | 34.7 | 29.1 | 32.1 | 25.6 | 22.2 | 20.8 | 25.8 | 28.3 | 36.7 | 37.8 | 39.0 | 36.1 | 30.9 |
| **97** | 35.5 | 33.0 | 35.3 | 33.1 | 31.7 | 28.7 | 29.9 | 33.7 | 35.8 | 40.9 | 34.7 | 32.5 | 33.7 |
| **102** | 44.5 | 40.9 | 35.9 | 31.9 | 29.6 | 25.6 | 27.8 | 31.6 | 33.0 | 40.0 | 42.4 | 45.8 | 35.7 |
| **104** | 27.3 | 26.5 | 26.3 | 20.6 | 24.5 | 19.7 | 23.4 | 23.1 | 26.2 | 22.8 | 26.2 | 33.4 | 25.1 |
| **Avg** | 36.5 | 34.5 | 33.0 | 29.4 | 28.0 | 25.2 | 27.8 | 30.6 | 34.1 | 38.1 | 38.7 | 39.8 | 32.9 |
| **SD** | 9.5 | 6.8 | 5.3 | 4.8 | 4.8 | 4.2 | 2.9 | 3.5 | 3.7 | 5.8 | 6.6 | 9.0 | |
| **SEM** | 2.9 | 2.0 | 1.6 | 1.5 | 1.5 | 1.3 | 0.9 | 1.0 | 1.1 | 1.8 | 2.0 | 2.7 | |
| **L(0.99893)** | 24.7 | 26.1 | 26.5 | 23.4 | 22.0 | 20.0 | 24.2 | 26.3 | 29.5 | 31.0 | 30.5 | 28.6 | |
| **U(0.99893)** | 48.3 | 42.9 | 39.6 | 35.4 | 33.9 | 30.4 | 31.5 | 34.9 | 38.7 | 45.3 | 46.9 | 51.0 | |
| **Lompoc** | | | | | | | | | | | | | |
| **H St.** | 36.1 | 36.3 | 33.3 | 28.9 | 29.2 | 26.2 | 27.7 | 32.1 | 35.1 | 40.0 | 44.0 | 47.0 | 34.7 |
| | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | |
| **HSP** | 33.1 | 31.7 | 29.6 | 29.5 | 30.4 | 28.4 | 33.5 | 36.1 | 38.7 | 37.8 | 36.2 | 38.5 | 33.6 |
| | ns | ns | ns | ns | ns | ns | **sig** | **sig** | **sig** | ns | ns | ns | |

Table 4. Comparison of simulation results for high mixing height and low mixing height scenarios for 11 CIMIS stations and two Lompoc stations. All units are s/m. The three measurements are highest, second and mean refers to highest 24-hour average, second highest and average over the period. For each mixing height and measurement combination, there are two statistics: 50th and 90th percentile.

| | HIGH MIXING HEIGHT | | | | | | LOW MIXING HEIGHT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CIMIS | Highest | | Second | | Mean | | Highest | | Second | | Mean | |
| Station | 50%tile | 90%tile | 50%tile | 90%tile | 50%tile | 90%tile | 50%tile | 90%tile | 50%tile | 90%tile | 50%tile | 90%tile |
| 16 | 0.64 | 2.46 | 0.52 | 1.73 | 0.07 | 0.32 | 1.03 | 2.83 | 0.78 | 2.33 | 0.15 | 0.64 |
| 19 | 0.57 | 1.74 | 0.46 | 1.39 | 0.06 | 0.24 | 0.98 | 2.52 | 0.79 | 2.07 | 0.11 | 0.50 |
| 49 | 0.67 | 2.04 | 0.52 | 1.72 | 0.07 | 0.33 | 1.13 | 2.71 | 0.96 | 2.41 | 0.19 | 0.74 |
| 52 | 0.76 | 2.38 | 0.61 | 1.86 | 0.07 | 0.32 | 1.40 | 3.66 | 1.15 | 3.12 | 0.17 | 0.83 |
| 64 | 0.73 | 2.08 | 0.55 | 1.66 | 0.07 | 0.37 | 1.01 | 3.39 | 0.82 | 2.95 | 0.11 | 0.90 |
| 66 | 0.87 | 2.59 | 0.70 | 2.25 | 0.08 | 0.33 | 1.35 | 3.65 | 1.18 | 3.31 | 0.21 | 0.71 |
| 94 | 0.59 | 1.95 | 0.48 | 1.57 | 0.05 | 0.35 | 1.18 | 2.79 | 1.04 | 2.42 | 0.26 | 0.77 |
| 95 | 0.65 | 1.93 | 0.48 | 1.76 | 0.07 | 0.28 | 0.96 | 2.48 | 0.77 | 2.26 | 0.15 | 0.56 |
| 97 | 0.83 | 2.47 | 0.60 | 1.82 | 0.07 | 0.32 | 1.22 | 3.10 | 0.96 | 2.58 | 0.14 | 0.72 |
| 102 | 0.86 | 2.46 | 0.64 | 2.10 | 0.08 | 0.33 | 1.37 | 3.38 | 1.11 | 2.80 | 0.22 | 0.84 |
| 104 | 0.73 | 2.08 | 0.56 | 1.78 | 0.08 | 0.32 | 1.56 | 3.55 | 1.35 | 3.12 | 0.31 | 0.85 |
| Avg | 0.72 | 2.20 | 0.56 | 1.79 | 0.07 | 0.32 | 1.20 | 3.10 | 0.99 | 2.67 | 0.18 | 0.73 |
| SD | 0.10 | 0.28 | 0.07 | 0.23 | 0.01 | 0.03 | 0.20 | 0.45 | 0.19 | 0.41 | 0.06 | 0.13 |
| SEM | 0.03 | 0.08 | 0.02 | 0.07 | 0.00 | 0.01 | 0.06 | 0.14 | 0.06 | 0.12 | 0.02 | 0.04 |
| L(.99893) | 0.59 | 1.85 | 0.46 | 1.50 | 0.06 | 0.28 | 0.95 | 2.54 | 0.75 | 2.16 | 0.11 | 0.58 |
| U(.99893) | 0.85 | 2.55 | 0.65 | 2.07 | 0.08 | 0.36 | 1.45 | 3.65 | 1.23 | 3.18 | 0.26 | 0.89 |
| Lompoc | | | | | | | | | | | | |
| H St. | 0.58 | 1.96 | 0.43 | 1.51 | 0.03 | 0.33 | 0.91 | 3.31 | 0.62 | 2.85 | 0.05 | 0.97 |
| | sig -lower | ns | sig-lower | ns | sig-lower | ns | sig-lower | ns | sig-lower | ns | sig-lower | sig-higher |
| HSP | 0.75 | 2.15 | 0.61 | 1.70 | 0.09 | 0.34 | 1.12 | 2.86 | 0.95 | 2.37 | 0.18 | 0.64 |
| | ns | ns | ns | ns | sig-higher | ns | ns | ns | ns | ns | ns | ns |
| % Diff | | | | | | | | | | | | |
| H St. | -19% | ns | -23% | ns | -57% | ns | -24% | ns | -37% | ns | -73% | 32% |
| HSP | ns | ns | ns | ns | 29% | ns | ns | ns | ns | ns | ns | ns |

Table 5a. Aerial (91A-94A) and ground (91G-94G) application counts by month for 1991-1994 for five AUI sections near Lompoc, California.

| Month | 91A | 92A | 93A | 94A | Mean | SD | 91G | 92G | 93G | 94G | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 5.00 | 4.00 | 4.00 | 16.00 | 7.25 | 5.85 | 56.00 | 67.00 | 5.00 | 48.00 | 44.00 | 27.14 |
| 2.00 | 6.00 | 27.00 | 27.00 | 17.00 | 19.25 | 10.01 | 95.00 | 81.00 | 15.00 | 79.00 | 67.50 | 35.72 |
| 3.00 | 32.00 | 58.00 | 30.00 | 26.00 | 36.50 | 14.55 | 36.00 | 223.00 | 143.00 | 145.00 | 136.75 | 76.80 |
| 4.00 | 26.00 | 44.00 | 10.00 | 14.00 | 23.50 | 15.26 | 196.00 | 304.00 | 211.00 | 208.00 | 229.75 | 49.92 |
| 5.00 | 21.00 | 56.00 | 42.00 | 38.00 | 39.25 | 14.41 | 221.00 | 232.00 | 168.00 | 228.00 | 212.25 | 29.85 |
| 6.00 | 25.00 | 51.00 | 19.00 | 16.00 | 27.75 | 15.95 | 211.00 | 283.00 | 215.00 | 227.00 | 234.00 | 33.37 |
| 7.00 | 30.00 | 16.00 | 9.00 | 9.00 | 16.00 | 9.90 | 190.00 | 261.00 | 201.00 | 275.00 | 231.75 | 42.48 |
| 8.00 | 29.00 | 15.00 | 25.00 | 10.00 | 19.75 | 8.77 | 220.00 | 217.00 | 190.00 | 226.00 | 213.25 | 15.95 |
| 9.00 | 12.00 | 5.00 | 21.00 | 0.00 | 9.50 | 9.11 | 194.00 | 230.00 | 143.00 | 264.00 | 207.75 | 51.77 |
| 10.00 | 13.00 | 0.00 | 4.00 | 14.00 | 7.75 | 6.85 | 148.00 | 1.00 | 140.00 | 325.00 | 153.50 | 132.77 |
| 11.00 | 16.00 | 8.00 | 8.00 | 23.00 | 13.75 | 7.23 | 38.00 | 36.00 | 51.00 | 176.00 | 75.25 | 67.50 |
| 12.00 | 8.00 | 4.00 | 34.00 | 0.00 | 11.50 | 15.35 | 52.00 | 20.00 | 51.00 | 97.00 | 55.00 | 31.70 |
| Total | 223.00 | 288.00 | 233.00 | 183.00 | 231.75 | 43.28 | 1657.00 | 1955.00 | 1533.00 | 2298.00 | 1860.75 | 341.08 |

Table 5b. Aerial (91A-94A) and ground (91G-94G) monthly fraction of application counts for 1991-1994 for five AUI sections near Lompoc, California.

| Month | 91A | 92A | 93A | 94A | Mean | S D | 91G | 92G | 93G | 94G | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 0.02 | 0.01 | 0.02 | 0.09 | 0.04 | 0.03 | 0.03 | 0.03 | 0.00 | 0.02 | 0.02 | 0.01 |
| 2.00 | 0.03 | 0.09 | 0.12 | 0.09 | 0.08 | 0.04 | 0.06 | 0.04 | 0.01 | 0.03 | 0.04 | 0.02 |
| 3.00 | 0.14 | 0.20 | 0.13 | 0.14 | 0.15 | 0.03 | 0.02 | 0.11 | 0.09 | 0.06 | 0.07 | 0.04 |
| 4.00 | 0.12 | 0.15 | 0.04 | 0.08 | 0.10 | 0.05 | 0.12 | 0.16 | 0.14 | 0.09 | 0.13 | 0.03 |
| 5.00 | 0.09 | 0.19 | 0.18 | 0.21 | 0.17 | 0.05 | 0.13 | 0.12 | 0.11 | 0.10 | 0.12 | 0.01 |
| 6.00 | 0.11 | 0.18 | 0.08 | 0.09 | 0.11 | 0.04 | 0.13 | 0.14 | 0.14 | 0.10 | 0.13 | 0.02 |
| 7.00 | 0.13 | 0.06 | 0.04 | 0.05 | 0.07 | 0.04 | 0.11 | 0.13 | 0.13 | 0.12 | 0.12 | 0.01 |
| 8.00 | 0.13 | 0.05 | 0.11 | 0.05 | 0.09 | 0.04 | 0.13 | 0.11 | 0.12 | 0.10 | 0.12 | 0.02 |
| 9.00 | 0.05 | 0.02 | 0.09 | 0.00 | 0.04 | 0.04 | 0.12 | 0.12 | 0.09 | 0.11 | 0.11 | 0.01 |
| 10.00 | 0.06 | 0.00 | 0.02 | 0.08 | 0.04 | 0.04 | 0.09 | 0.00 | 0.09 | 0.14 | 0.08 | 0.06 |
| 11.00 | 0.07 | 0.03 | 0.03 | 0.13 | 0.06 | 0.04 | 0.02 | 0.02 | 0.03 | 0.08 | 0.04 | 0.03 |
| 12.00 | 0.04 | 0.01 | 0.15 | 0.00 | 0.05 | 0.07 | 0.03 | 0.01 | 0.03 | 0.04 | 0.03 | 0.01 |

Table 6. Tukey's multiple means comparison for average monthly fraction of yearly applications for aerial and ground applications in five AUI sections. Means with different letters indicate significant differences at the 5% level. For example, for aerial applications, March (month=3) is statistically different from Jan (month=1), Oct (month=10), and September (month=9), but not from any other months.

| Aerial | | Ground | |
|---|---|---|---|
| Month | Fraction of Applicat. | Month | Fraction of Applicat. |
| 1 | 0.04 a | 1 | 0.02 a |
| 10 | 0.04 a | 12 | 0.03 a |
| 9 | 0.04 a | 2 | 0.04 a |
| 12 | 0.05 ab | 11 | 0.04 a |
| 11 | 0.06 abc | 3 | 0.07 ab |
| 7 | 0.07 abc | 10 | 0.08 ab |
| 2 | 0.08 abc | 9 | 0.11 b |
| 8 | 0.09 abc | 5 | 0.12 b |
| 4 | 0.10 abc | 8 | 0.12 b |
| 6 | 0.11 abc | 7 | 0.12 b |
| 3 | 0.15 bc | 4 | 0.13 b |
| 5 | 0.17 c | 6 | 0.13 b |

Table 7. Frequency of maximum 45 degree sector wind direction count by month by station for 11 CIMIS stations and two Lompoc stations. Each entry is fraction of hours where wind direction was in the maximum 45 degree sector. To convert fraction to percentage, multiply by 100. S.D is standard deviation. S.E.M. is standard error of the mean. L(0.99893) and U(.99893) refer to lower and upper 99.893% confidence bounds calculated by average ± S.E.M.*4.10. The March through October H St. frequencies were significantly greater at the 5% level than the average CIMIS frequencies. The HSP frequencies were not significantly different than the CIMIS frequencies.

| Station | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **16** | 0.66 | 0.54 | 0.42 | 0.36 | 0.42 | 0.39 | 0.47 | 0.41 | 0.42 | 0.35 | 0.55 | 0.67 |
| **19** | 0.33 | 0.28 | 0.24 | 0.30 | 0.40 | 0.36 | 0.43 | 0.39 | 0.36 | 0.24 | 0.31 | 0.31 |
| **49** | 0.32 | 0.31 | 0.27 | 0.33 | 0.40 | 0.39 | 0.40 | 0.39 | 0.33 | 0.34 | 0.42 | 0.45 |
| **52** | 0.28 | 0.25 | 0.25 | 0.40 | 0.46 | 0.47 | 0.49 | 0.42 | 0.39 | 0.25 | 0.25 | 0.26 |
| **64** | 0.22 | 0.24 | 0.28 | 0.36 | 0.45 | 0.53 | 0.60 | 0.57 | 0.52 | 0.38 | 0.28 | 0.25 |
| **66** | 0.29 | 0.26 | 0.25 | 0.21 | 0.26 | 0.25 | 0.28 | 0.21 | 0.22 | 0.23 | 0.32 | 0.32 |
| **94** | 0.34 | 0.32 | 0.28 | 0.17 | 0.25 | 0.27 | 0.33 | 0.38 | 0.34 | 0.31 | 0.26 | 0.29 |
| **95** | 0.37 | 0.27 | 0.28 | 0.29 | 0.35 | 0.31 | 0.41 | 0.30 | 0.32 | 0.25 | 0.38 | 0.35 |
| **97** | 0.32 | 0.27 | 0.23 | 0.37 | 0.45 | 0.42 | 0.48 | 0.47 | 0.40 | 0.24 | 0.35 | 0.33 |
| **102** | 0.19 | 0.19 | 0.21 | 0.24 | 0.34 | 0.36 | 0.35 | 0.23 | 0.24 | 0.23 | 0.25 | 0.24 |
| **104** | 0.35 | 0.30 | 0.29 | 0.32 | 0.16 | 0.20 | 0.19 | 0.18 | 0.19 | 0.26 | 0.32 | 0.31 |
| **Mean** | 0.33 | 0.29 | 0.27 | 0.30 | 0.36 | 0.36 | 0.40 | 0.36 | 0.34 | 0.28 | 0.33 | 0.34 |
| **SD** | 0.12 | 0.09 | 0.05 | 0.07 | 0.10 | 0.10 | 0.11 | 0.12 | 0.10 | 0.05 | 0.09 | 0.12 |
| **SEM** | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.03 | 0.04 |
| **L(0.99893)** | 0.18 | 0.18 | 0.21 | 0.22 | 0.24 | 0.24 | 0.26 | 0.21 | 0.22 | 0.21 | 0.22 | 0.19 |
| **U(0.99893)** | 0.48 | 0.41 | 0.34 | 0.39 | 0.48 | 0.48 | 0.54 | 0.50 | 0.46 | 0.35 | 0.44 | 0.49 |
| **Lompoc** | | | | | | | | | | | | |
| **H St.** | 0.34 | 0.32 | 0.43 | 0.65 | 0.68 | 0.75 | 0.76 | 0.75 | 0.67 | 0.50 | 0.44 | 0.39 |
| | ns | ns | sig | sig | sig | sig | sig | sig | sig | sig | ns | ns |
| **HSP** | 0.28 | 0.24 | 0.22 | 0.35 | 0.31 | 0.36 | 0.42 | 0.40 | 0.33 | 0.23 | 0.32 | 0.29 |
| | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

Table 8. Wind speed histograms for 11 CIMIS stations and two Lompoc stations in 2 mile per hour (mph) bins. Frequencies are shown here as percentages. Bins are 0-2 mph, 2-4 mph, 4-6 mph, etc. #hours refers to the number of wind speed measurements used in determining the frequency. SD and SEM are standard deviation and standard error of the mean. L(.9984) and U(.9984) refer to lower and upper bounds of 99.84% confidence interval corresponding to experimentwise 95% confidence interval for 16 comparisons. Upper and lower confidence bounds calculated as average±SEM*3.852, which corresponds to two tailed $t_{10}$ value for .9984. Only the first 8 bins were compared due to small frequencies in bins with higher wind speeds. The H St. station was significantly lower than the average CIMIS stations in the 2-4 mph category only. The HSP station frequency was significantly lower than the CIMIS station frequency in the 0-2 mph category and significantly higher than the CIMIS stations in 10-12 mph and 12-14 mph categories. The remaining comparisons were not significant.

| Station | <=2 | <=4 | <=6 | <=8 | <=10 | <=12 | <=14 | <=16 | <=18 | <=20 | >20 | Total | #hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **016** | 20.2 | 29.7 | 18.7 | 13.8 | 10.6 | 5.1 | 1.4 | 0.3 | 0.1 | 0.0 | 0.0 | 99.9 | 29959 |
| **019** | 6.2 | 30.8 | 21.1 | 15.1 | 12.6 | 7.4 | 3.6 | 1.7 | 0.9 | 0.5 | 0.3 | 100.2 | 34429 |
| **049** | 34.3 | 30.7 | 13.9 | 16.5 | 3.8 | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 100.1 | 25472 |
| **052** | 20.0 | 37.5 | 21.5 | 16.0 | 4.1 | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 34981 |
| **064** | 28.8 | 36.4 | 13.8 | 10.5 | 6.7 | 2.6 | 0.9 | 0.2 | 0.1 | 0.0 | 0.0 | 100.0 | 34572 |
| **066** | 32.4 | 32.1 | 20.7 | 13.1 | 1.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 34169 |
| **094** | 12.9 | 44.4 | 27.1 | 8.5 | 3.8 | 1.9 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 | 99.9 | 34622 |
| **095** | 11.6 | 36.7 | 20.0 | 11.8 | 7.8 | 5.2 | 3.4 | 1.8 | 0.9 | 0.5 | 0.3 | 100.0 | 23800 |
| **097** | 21.1 | 31.3 | 17.4 | 17.6 | 8.9 | 2.6 | 0.8 | 0.2 | 0.1 | 0.0 | 0.0 | 100.0 | 34703 |
| **102** | 39.2 | 31.2 | 23.8 | 4.9 | 0.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.1 | 32506 |
| **104** | 29.2 | 50.8 | 18.4 | 1.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.1 | 32948 |
| | | | | | | | | | | | | | |
| **Mean** | 23.3 | 35.6 | 19.7 | 11.8 | 5.5 | 2.4 | 1.0 | 0.4 | 0.2 | 0.1 | 0.1 | | |
| **SD** | 10.4 | 6.7 | 3.9 | 5.1 | 4.1 | 2.5 | 1.3 | 0.7 | 0.3 | 0.2 | 0.1 | | |
| **SEM** | 3.1 | 2.0 | 1.2 | 1.5 | 1.2 | 0.7 | 0.4 | 0.2 | 0.1 | 0.1 | 0.0 | | |
| **L(.9984)** | 11.2 | 27.8 | 15.1 | 5.9 | 0.7 | -0.5 | -0.5 | -0.4 | | | | | |
| **U(.9984)** | 35.4 | 43.4 | 24.2 | 17.6 | 10.3 | 5.3 | 2.6 | 1.2 | | | | | |
| | | | | | | | | | | | | | |
| **H St** | 28.6 | 25.1 | 17.3 | 14.9 | 8.6 | 3.8 | 1.0 | 0.4 | 0.2 | 0.1 | 0.0 | 100.0 | 33804 |
| | ns | sig low | ns | ns | ns | ns | ns | ns | | | | | |
| **HSP** | 11.1 | 36.3 | 19.4 | 12.6 | 9.9 | 7.2 | 2.7 | 0.6 | 0.1 | 0.0 | 0.0 | 99.9 | 34773 |
| | sig low | ns | ns | ns | ns | sig high | sig high | ns | | | | | |

Table 9. Monthly wind speed frequencies for H St. and HSP stations in Lompoc. Frequencies are shown as percentages. Bin units are mph. First bin is 0-2 mph, etc.

| **H St.** | 0 to 2 | 2 to 4 | 4 to 6 | 6 to 8 | 8 to 10 | 10 to 12 | 12 to 14 | 14 to 16 | 16 to 18 | 18 to 20 | >20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 36.6 | 26.7 | 12.0 | 9.7 | 6.5 | 3.6 | 1.8 | 1.6 | 0.6 | 0.5 | 0.5 |
| FEB | 32.0 | 26.2 | 14.2 | 12.1 | 7.9 | 3.7 | 1.7 | 1.2 | 0.8 | 0.1 | 0.1 |
| MAR | 30.0 | 23.2 | 16.7 | 13.8 | 9.2 | 4.5 | 1.3 | 0.6 | 0.3 | 0.1 | 0.1 |
| APR | 20.6 | 16.4 | 20.4 | 18.2 | 12.7 | 9.2 | 1.7 | 0.5 | 0.3 | 0.0 | 0.0 |
| MAY | 20.2 | 19.1 | 20.3 | 18.5 | 12.2 | 7.1 | 2.0 | 0.4 | 0.1 | 0.0 | 0.0 |
| JUN | 17.1 | 22.7 | 20.3 | 19.7 | 13.6 | 5.8 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| JUL | 17.5 | 29.6 | 21.2 | 20.4 | 9.2 | 1.9 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| AUG | 22.8 | 24.1 | 21.7 | 18.8 | 9.9 | 2.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEP | 24.4 | 32.1 | 17.8 | 17.3 | 6.3 | 1.6 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| OCT | 35.6 | 28.2 | 15.8 | 11.8 | 6.1 | 2.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| NOV | 40.2 | 25.8 | 14.4 | 11.0 | 5.9 | 2.1 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 |
| DEC | 43.6 | 27.0 | 13.1 | 8.6 | 4.4 | 1.6 | 1.0 | 0.4 | 0.1 | 0.2 | 0.1 |
| TOT | 28.6 | 25.1 | 17.3 | 14.9 | 8.6 | 3.8 | 1.0 | 0.4 | 0.2 | 0.1 | 0.0 |

| **HSP** | 0 to 2 | 2 to 4 | 4 to 6 | 6 to 8 | 8 to 10 | 10 to 12 | 12 to 14 | 14 to 16 | 16 to 18 | 18 to 20 | >20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 7.3 | 35.8 | 24.9 | 15.6 | 8.2 | 4.2 | 2.2 | 1.0 | 0.5 | 0.2 | 0.1 |
| FEB | 7.5 | 33.7 | 23.4 | 14.5 | 10.7 | 5.9 | 2.8 | 1.2 | 0.2 | 0.1 | 0.0 |
| MAR | 5.5 | 35.4 | 23.1 | 15.4 | 11.8 | 6.1 | 1.7 | 0.4 | 0.3 | 0.1 | 0.2 |
| APR | 6.0 | 33.6 | 20.8 | 15.0 | 12.0 | 8.7 | 3.4 | 0.4 | 0.0 | 0.0 | 0.0 |
| MAY | 9.2 | 36.3 | 16.5 | 10.3 | 10.1 | 10.3 | 5.6 | 1.4 | 0.2 | 0.1 | 0.0 |
| JUN | 11.7 | 35.9 | 14.9 | 9.8 | 10.5 | 11.0 | 5.1 | 0.9 | 0.2 | 0.0 | 0.0 |
| JUL | 15.0 | 39.9 | 12.3 | 8.7 | 9.2 | 11.3 | 3.3 | 0.4 | 0.0 | 0.0 | 0.0 |
| AUG | 19.2 | 35.7 | 12.8 | 8.4 | 9.6 | 9.9 | 4.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| SEP | 22.0 | 37.2 | 13.1 | 8.3 | 9.4 | 8.0 | 1.9 | 0.1 | 0.0 | 0.0 | 0.0 |
| OCT | 14.1 | 37.4 | 18.6 | 12.4 | 10.4 | 5.4 | 1.4 | 0.3 | 0.0 | 0.0 | 0.0 |
| NOV | 7.8 | 36.1 | 25.7 | 17.9 | 9.4 | 2.9 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEC | 8.2 | 38.0 | 27.6 | 14.6 | 7.5 | 2.6 | 1.0 | 0.3 | 0.3 | 0.1 | 0.0 |
| Total | 11.1 | 36.6 | 19.4 | 12.6 | 9.9 | 7.2 | 2.7 | 0.6 | 0.1 | 0.0 | 0.0 |

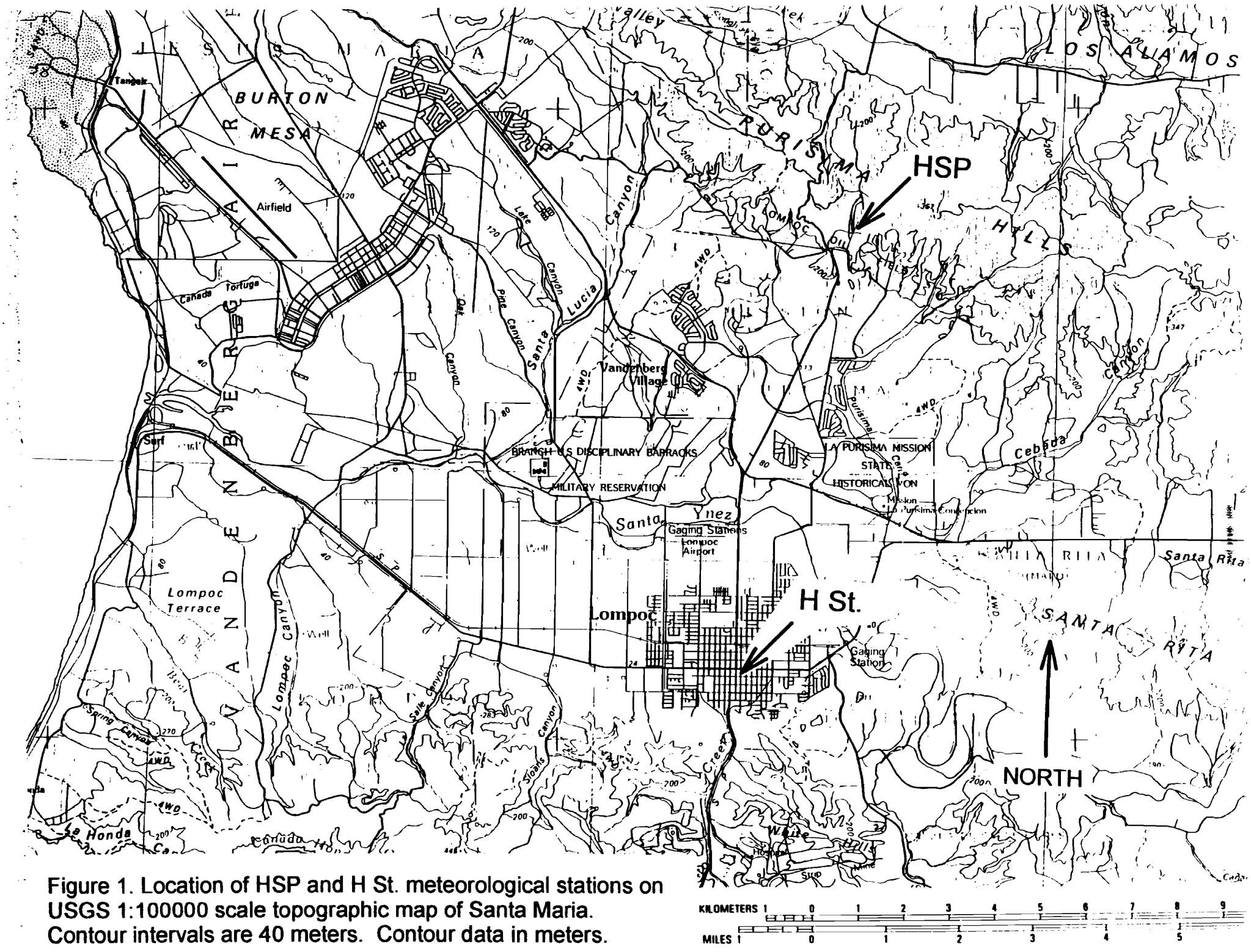



Figure 1. Location of HSP and H St. meteorological stations on USGS 1:100000 scale topographic map of Santa Maria. Contour intervals are 40 meters. Contour data in meters.

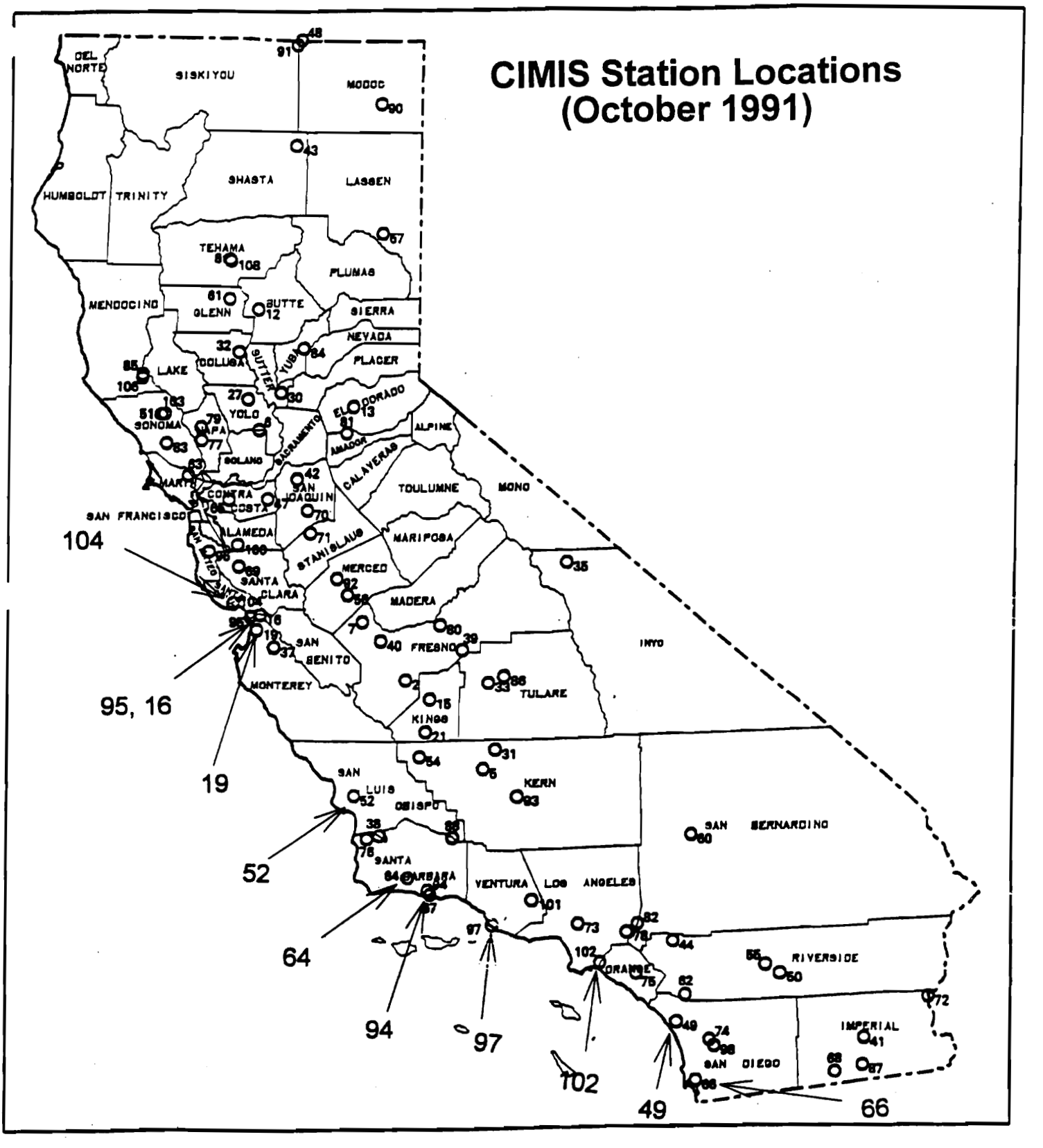



Figure 2. Statewide CIMIS station locations with 11 CIMIS stations used in study highlighted.

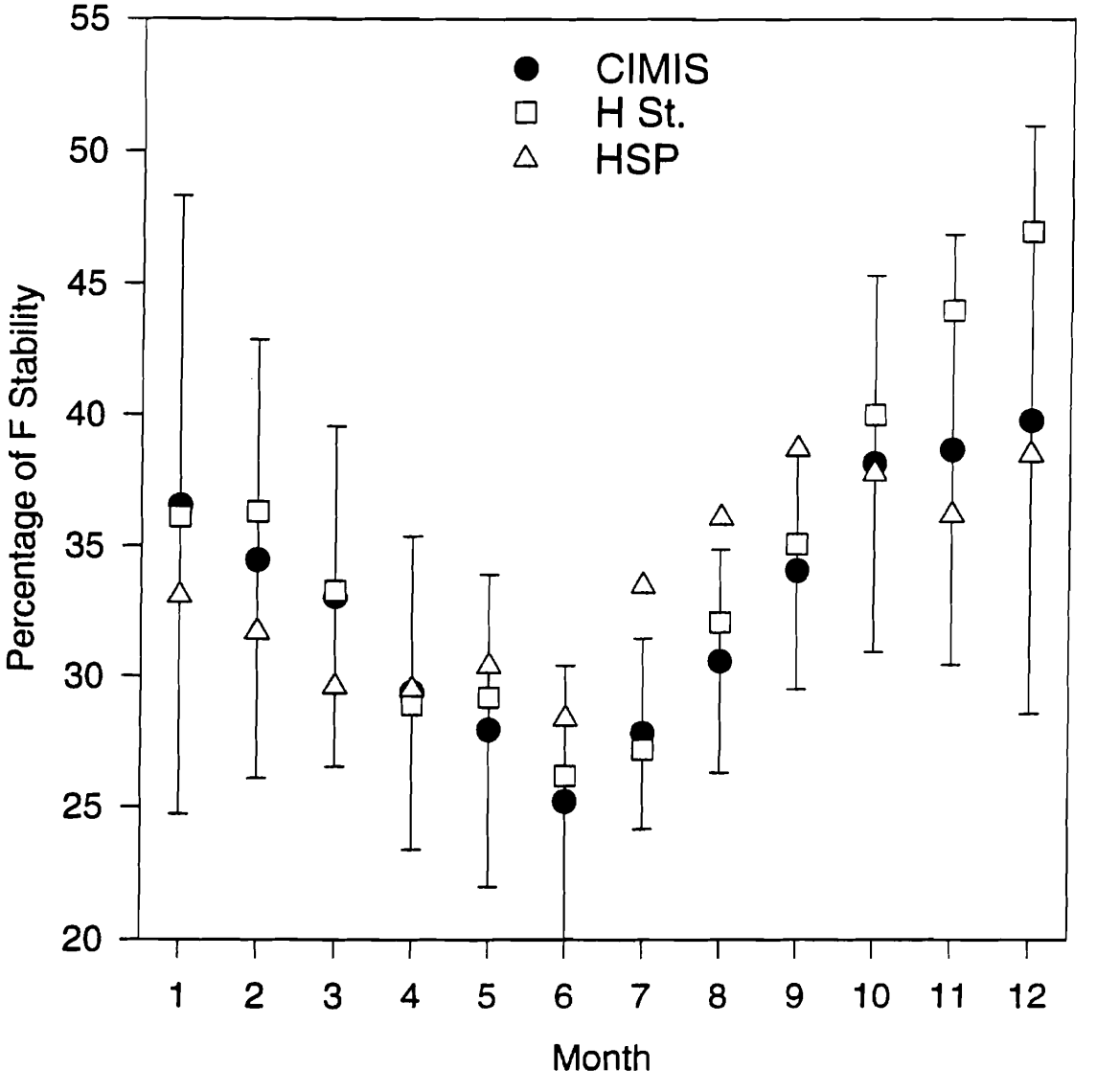



Figure 3. Percentage of stability class F by month for H St. and HSP sites compared to 11 CIMIS coastal weather stations. Error bars represent 99.893% confidence interval based on CIMIS data.

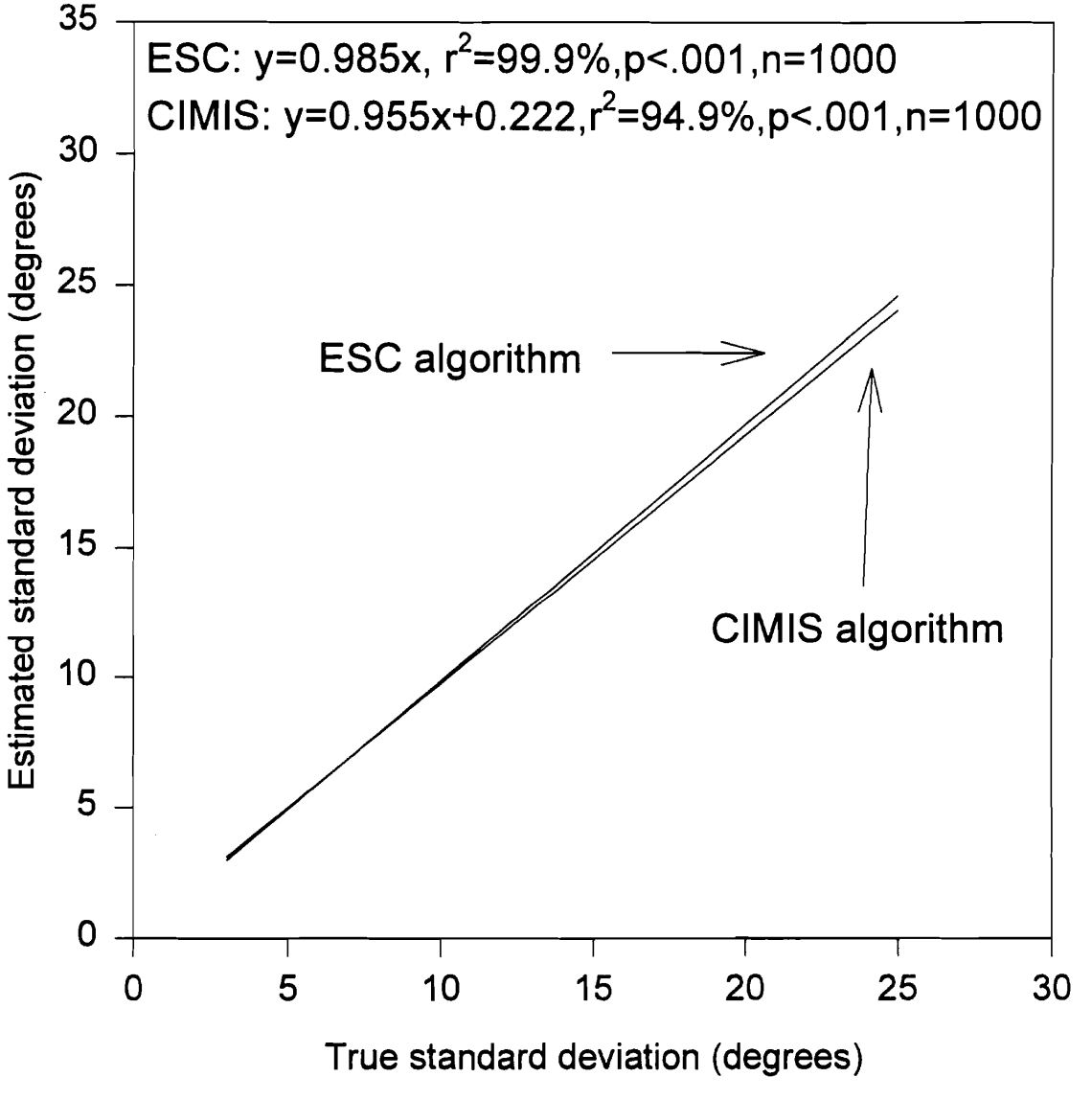



Figure 4. Comparison of ESC and CIMIS algorithms to simulated wind speed and direction data over a range of simulated standard deviations. ESC algorithm provides close estimate of standard deviation. CIMIS algorithm slightly overestimates at low values for the standard deviation of wind direction, which largely determine F stability frequency.

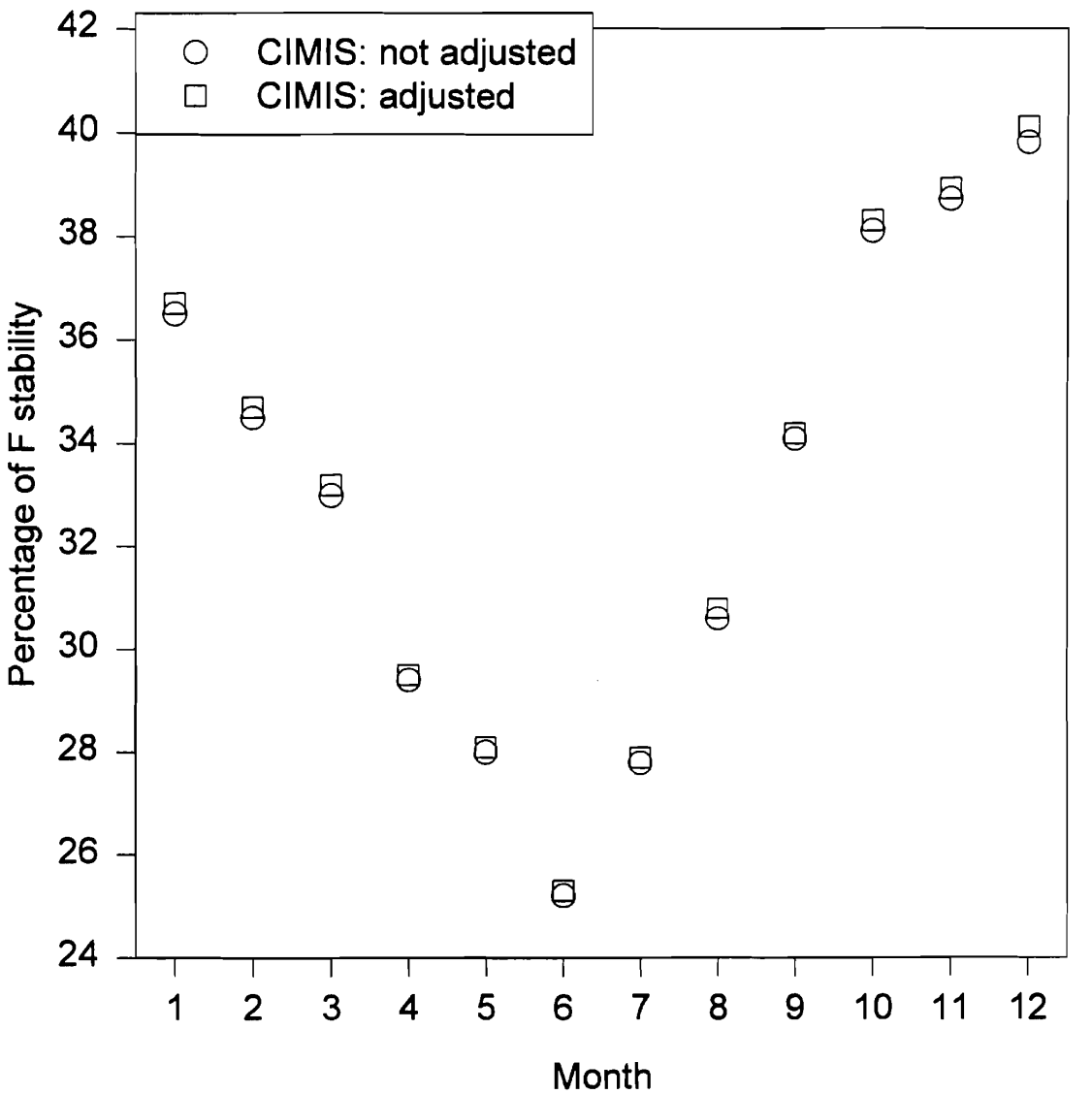



Figure 5. Impact on average values from CIMIS data of adjusting the standard deviation of wind direction in order to approximate the ESC algorithm.

Figure 6. Mean normalized air concentration values (s/m) from July data for 11 CIMIS stations and Lompoc HSP station under high mixing height condition. X and Y coordinates are meters. Field was located in center of each grid (see text).

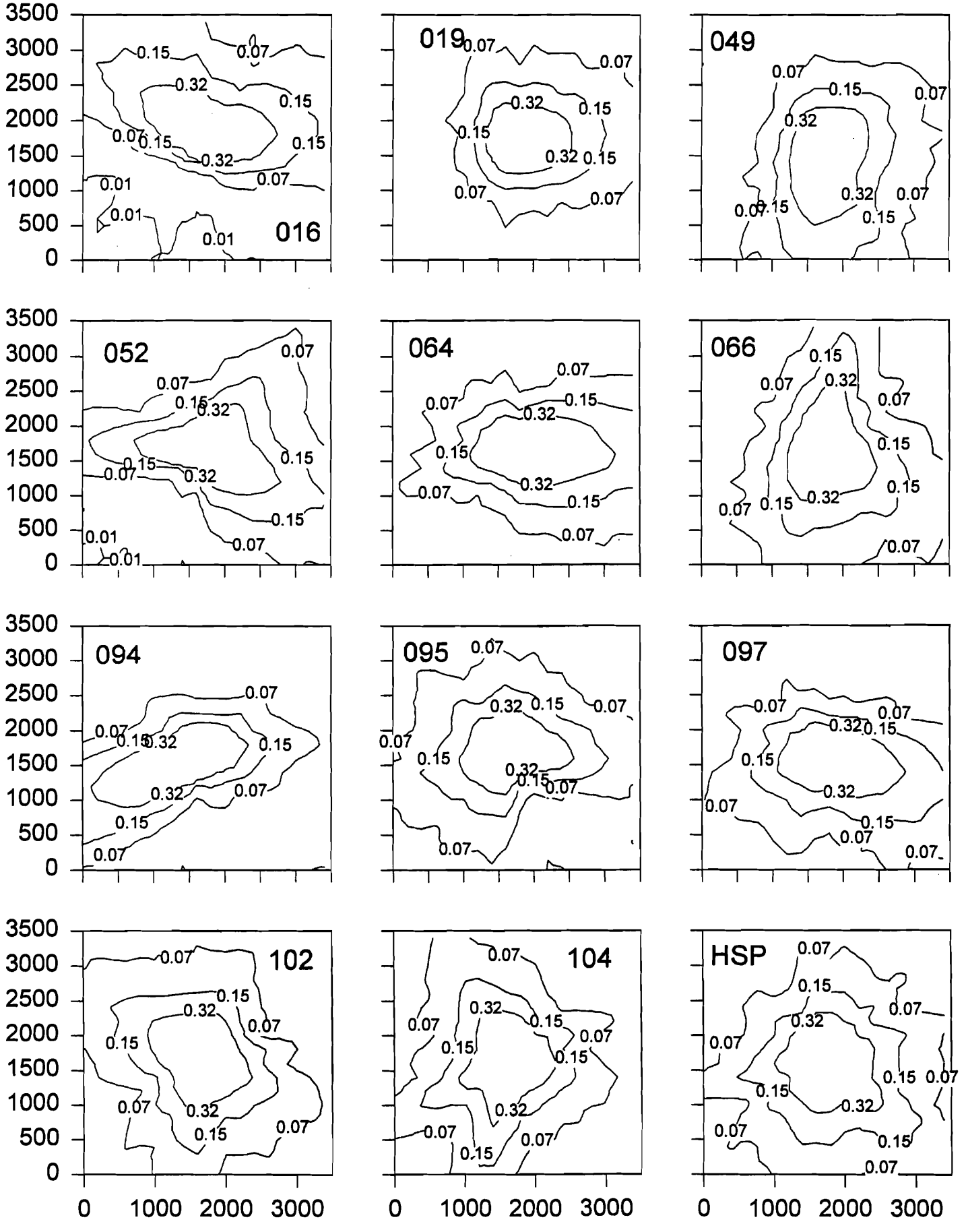
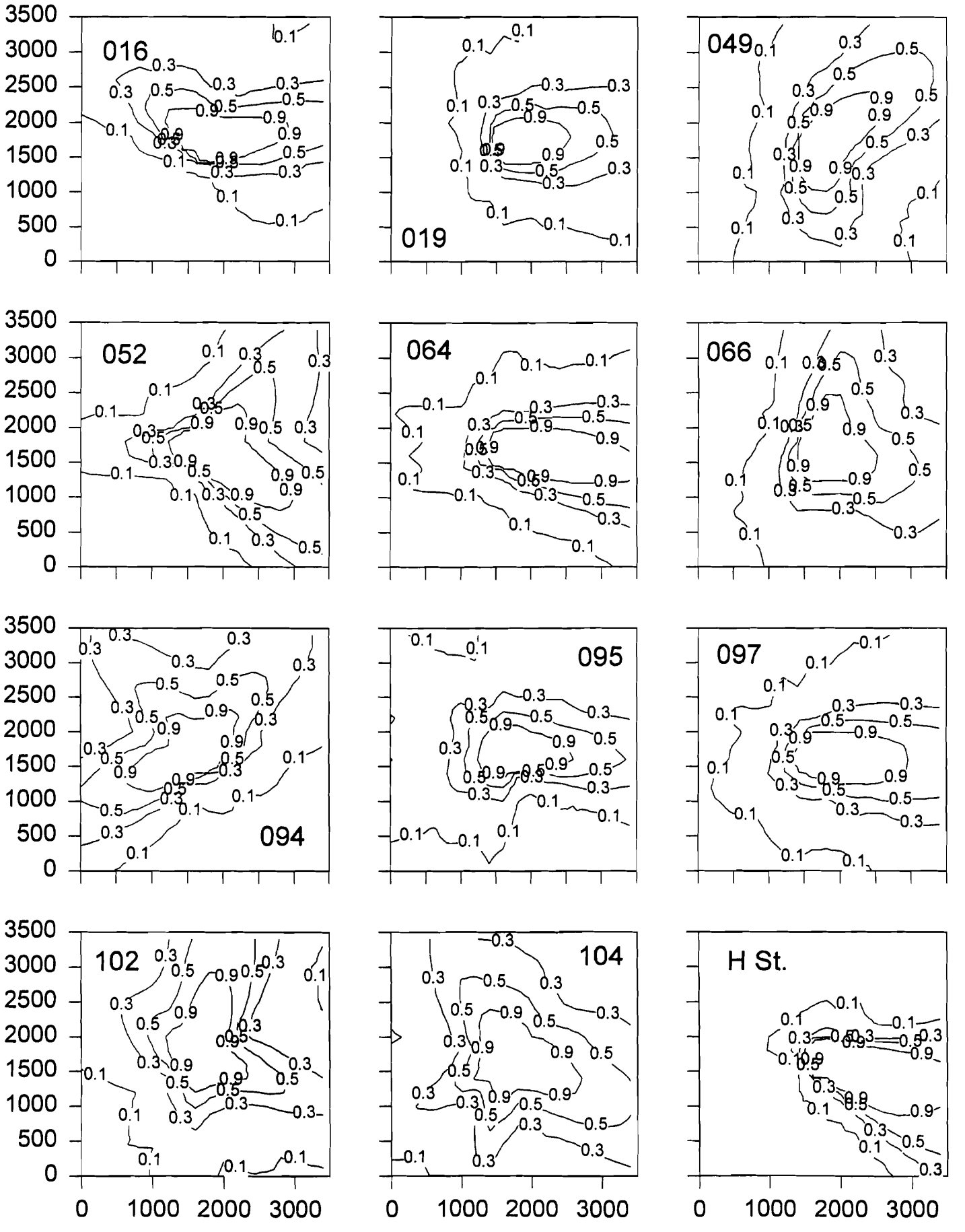

016
019
049
052
064
066
094
095
097
102
104
HSP
0.01
0.07
0.15
0.32
0
500
1000
1500
2000
2500
3000
3500

Figure 7. Mean normalized air concentration values (s/m) from July data for 11 CIMIS stations and Lompoc H St. station under low mixing height condition. X and Y coordinates are meters. Field was located in center of each grid (see text).


016
019
049
052
064
066
094
095
097
102
104
H St.
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000

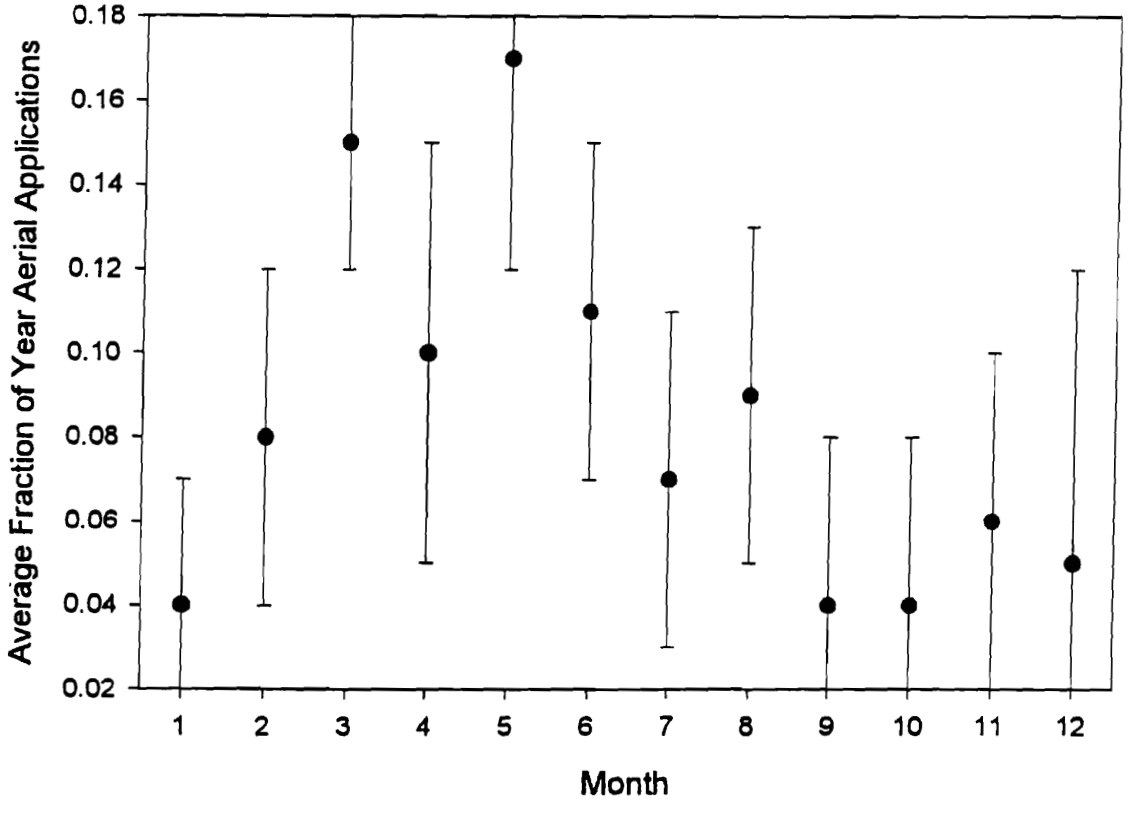



Figure 8. Average monthly fraction over 1991-1994 of aerial applications (mean +/- s.d.).

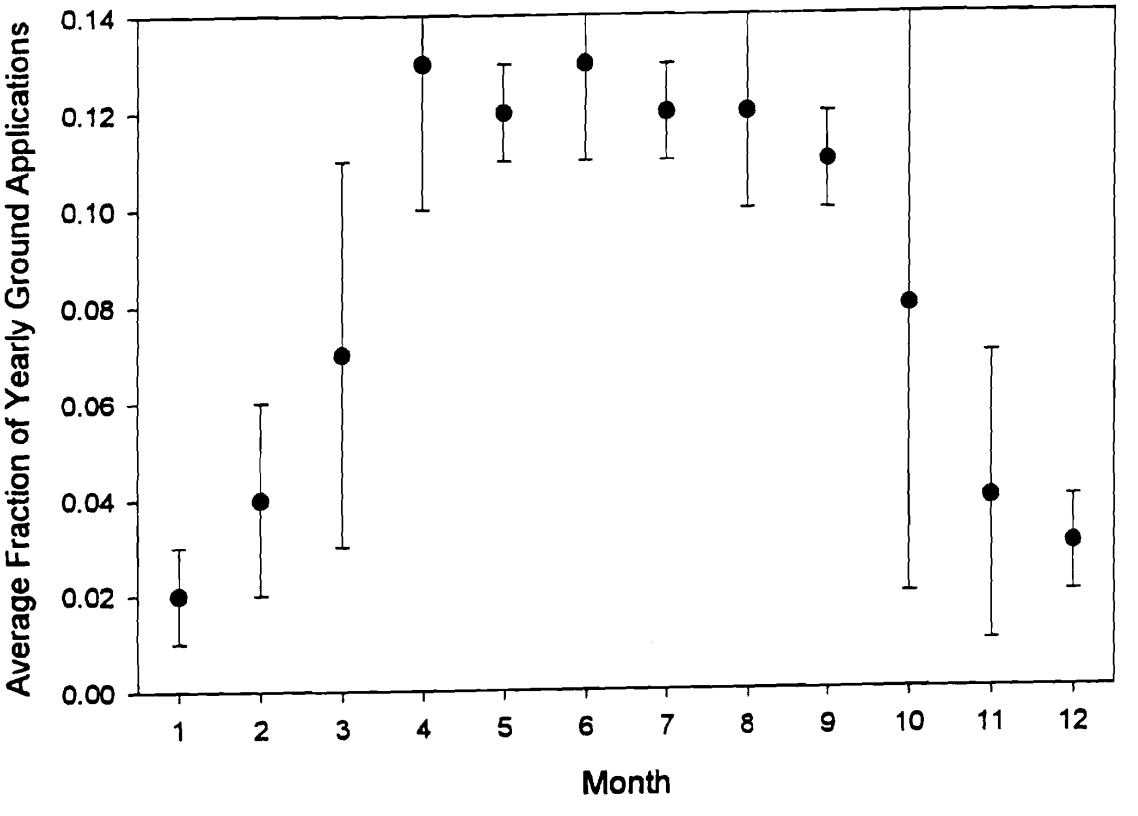



Figure 9. Average monthly fraction over 1991-1994 of ground applications (mean +/- s.d.).

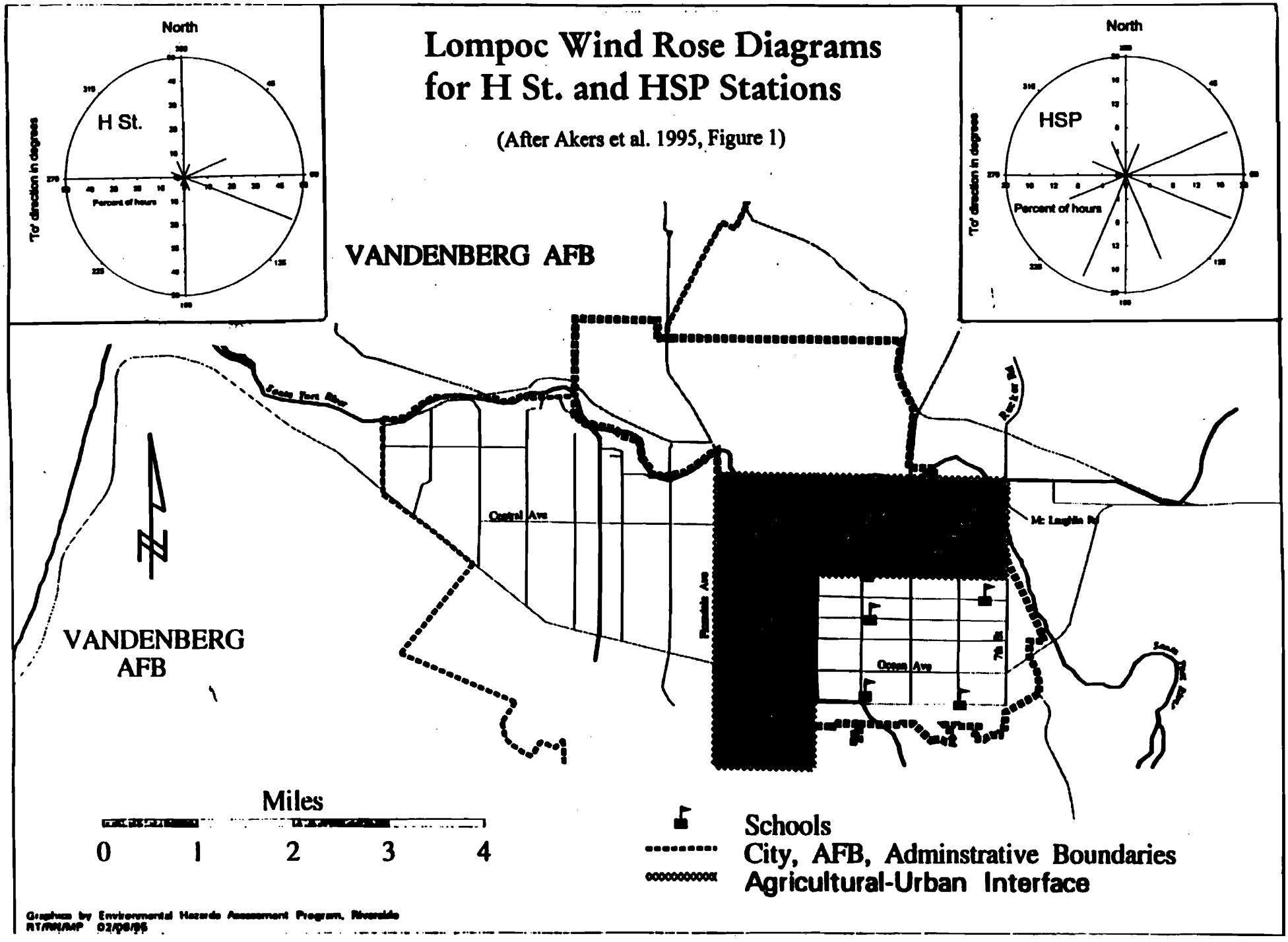



Figure 10. Wind rose diagrams for H St. and HSP stations in relation to Lompoc. Wind directions are frequencies indicating the 'to' direction and are centers of 45° sectors. Length of line segments corresponds to frequency of wind in that direction.

# Appendices

A1. Metacode for determining stability class

A2. Wind vector calculations utilized by CIMIS dataloggers and derivation of standard deviation equation.

A3. Six reviews of 12/97 draft.

A4. Responses to reviewers.

A5. Estimation of air monitoring variability.

# META CODE FOR DETERMINING STABILITY CLASS
(based on EPA Table 9-3, 9-4)

1. Obtain data

   a. net radiation (rad)
   b. wind velocity (wvel)
   c. standard deviation of wind direction (sd)
   d. stability from previous hour (ostab)

2. Perform preliminary (prestab) classification of stability based on standard deviation of wind direction

   a. if sd > 22.5, prestab = 1
   b. if 22.5 >= sd >17.5, prestab = 2
   c. if 17.5 >= sd > 12.5, prestab = 3
   d. if 12.5 >= sd > 7.5, prestab = 4
   e. if 7.5 >= sd > 3.8, prestab = 5
   f. if 3.8 >= sd, prestab = 6.

3. Determine if night or day

   a. if rad >= 0, it is day, skip step 4 and go to step 5
   b. if rad < 0, it is night, go to step 4

4. It is night, modify stability class according to Table 9-4

   a. if prestab = 1,
      i. if wvel < 2.9, then prestab=6
      ii. if 2.9<=wvel < 3.6, then prestab=5
      iii. if 3.6<=wvel, then prestab=4
      iv. go to step 5

   b. if prestab = 2
      i. if wvel < 2.4, then prestab=6
      ii. if 2.4<=wvel<3.0, then prestab=5
      iii. if 3.0<=wvel, then prestab=4
      iv. go to step 5

   c. if prestab = 3
      i. if wvel<2.4, then prestab=5
      ii. if wvel>=2.4, then prestab=4
      iii. goto step 5

5. Only allow 1 step change in stability class

   a. If the difference between ostab and prestab is less than 2, then stabclass=prestab
   b. If the difference between ostab and prestab is 2 or more, then
      i. If ostab-prestab<=-2
         (1) stabclass=ostab+1
         (2) go to step 6

      ii. if ostab-prestab>=2
         (1) stabclass=ostab-1
         (2) go to step 6

6. Report value of stabclass

| PARAMETER NUMBER | DATA TYPE | DESCRIPTION |
|---|---|---|
| 01: | 2 | Repetitions |
| 02: | 4 | Number of bins |
| 03: | 2 | Form code (0=open form, 1=closed form) |
| 04: | 4 | Bin select value input location no. |
| 05: | 4 | Weighted value input location no. (0 = frequency distribution option) |
| 06: | FP | Lower limit of range |
| 07: | FP | Upper limit of range |

OUTPUTS GENERATED — NUMBER OF BINS * REPETITIONS
INTERMEDIATE STORAGE — NUMBER OF REPETITIONS * BINS + 1
EXECUTION TIME — 0.4ms + 3.1ms * Reps (w/o Output Flag)
0.9ms + Reps (3.3ms + 2.8ms * Bins) (Output Flag set)

## **** 76 WIND VECTOR ****

FUNCTION

Output in order:

1. Mean wind speed
2. Mean wind vector magnitude
3. Mean wind vector direction
4. Standard deviation of direction

This instruction will work with either polar (wind speed and direction) or orthogonal (fixed East and North props) sensors and accommodates multiple sets of sensors through the "repetitions" parameter. When used with polar sensors, the wind direction in degrees may be 0 to 360, 0 to 540, less than zero, or greater than 540. This instruction does a modulo divide by 360 which enables it to handle all ranges.. The ability to handle a negative reading is useful in an example where a difficult to reach wind vane is improperly oriented and outputs 0 degrees at a true reading of 340 degrees. The simplist solution is an offset of -20 which results in a -20 to 340 degree output.

| PARAMETER NUMBER | DATA TYPE | DESCRIPTION |
|---|---|---|
| 01: | 2 | Repetitions of wind speed and direction |
| 02: | 2 | Sensor type: Enter 0 when inputs are wind speed and direction; enter 1 when inputs are orthogonal (East and North) wind speeds. |
| 03: | 4 | First wind speed input location no. (East wind speed) |
| 04: | 4 | First wind direction input location no. (North wind speed) |



[CAMPBELL SCIENTIFIC (1987)]

| | |
|---|---|
| OUTPUTS GENERATED | 4 FOR EACH REPETITION |
| INTERMEDIATE STORAGE | 3 FOR EACH REPETITION + 1 |
| EXECUTION TIME | 1.0ms + 14.2ms * Reps (μ, V; w/o Output Flag) |
| | 1.0ms + 58.2ms * Reps (Output Flag set) |
| | 0.8ms + 15.5ms * Reps (WS, WD; w/o Output Flag) |
| | 1.0ms + 59.0ms * Reps (Output Flag set) |

CALCULATION OF QUANTITIES OUTPUT BY WIND VECTOR

A2.2

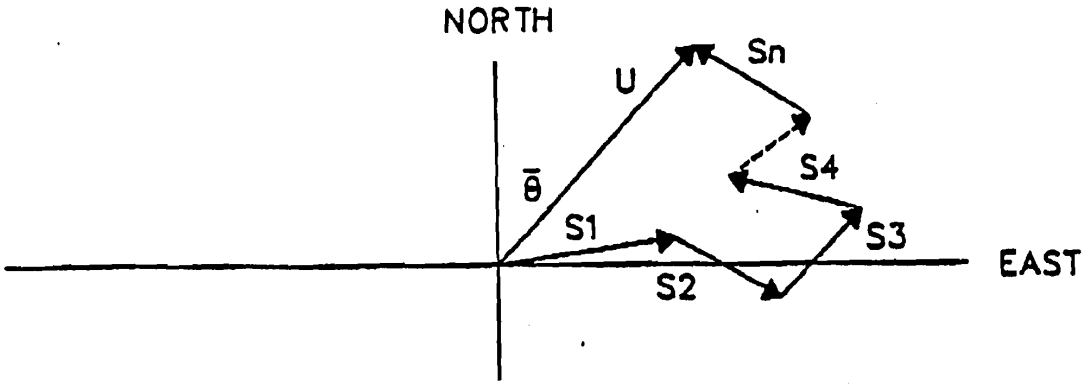



FIGURE 6.2-1. Input Sample Vectors

In Figure 6.2-1, the short, head-to-tail vectors are the input sample vectors described by Si and θi, the sample speed and direction, or by xi and yi, the east and north components of the sample vector. At the end of output interval T, the sum of the sample vectors is described by a vector of magnitude U and direction $\bar{\theta}$. If the input sample interval is t, the number of samples in output interval T is N = T/t. The mean vector magnitude, $\bar{U}$, is recorded, where $\bar{U} = U/N$.

Output 1: Mean wind speed ($\bar{S}$)

$$\bar{S} = \sum_{i=1}^{N} Si/N \qquad [6.2\text{-}1]$$

Where, for orthogonal wind speeds,

$$Si = (xi^2 + yi^2)^{1/2} \qquad [6.2\text{-}2]$$

Output 2: Mean wind vector magnitude ($\bar{U}$)

$$\bar{U} = (x^2 + y^2)^{1/2} \qquad [6.2\text{-}3]$$

Where x and y are defined as (Figure 6.2-2):

$$\bar{x} = \sum_{i=1}^{N} S_i \sin(\theta_i)/N; \quad \bar{y} = \sum_{i=1}^{N} S_i \cos(\theta_i)/N \qquad [6.2\text{-}4]$$

A2.3

Or, in the case of orthogonal inputs:

$$\bar{x} = \sum_{i=1}^{N} x_i/N; \quad \bar{y} = \sum_{i=1}^{N} y_i/N \qquad [6.2\text{-}5]$$

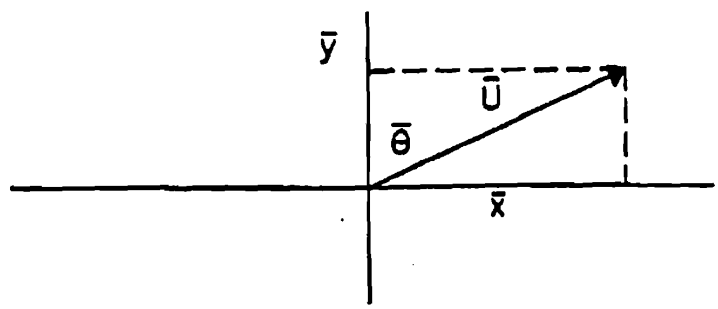



FIGURE 6.2-2. Mean Wind Vector

Output 3: Mean wind vector direction ($\bar{\theta}$)

$$\bar{\theta} = \arctan(\bar{x}/\bar{y}) \qquad [6.2\text{-}6]$$

Where the range is $0 < \bar{\theta} < 360$ degrees.

Output 4: Standard deviation of direction about $\theta$

$$\sigma(\theta) = 81\,(1 - \bar{U}/\bar{S})^{1/2} \qquad [6.2\text{-}7]$$

The algorithm for $\sigma(\theta)$ is developed by noting (Figure 6.2-3) that

$$\cos(\theta_i') = U_i/S_i; \text{ where } \theta_i' = \theta_i - \bar{\theta}. \qquad [6.2\text{-}8]$$

$$\sigma(\theta) = 81\left(1 - \frac{\bar{u}}{\bar{s}}\right)^{\frac{1}{2}}$$

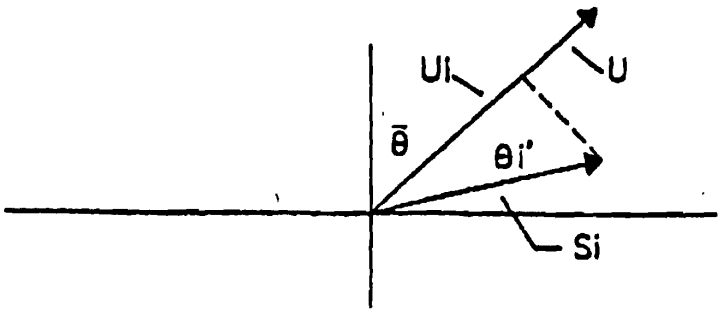



FIGURE 6.2-3. Standard Deviation of Direction

The Taylor Series for the Cosine function, truncated after 2 terms is:

$$\cos(\theta i') \approx 1 - (\theta i')^2/2 \qquad [6.2\text{-}9]$$

For deviations less than 40 degrees, the error in this approximation is less than 1%. At deviations of 60 degrees, the error is 10%.

The speed sample may be expressed as the deviation about the mean speed,

$$Si = Si' + \bar{S} \qquad [6.2\text{-}10]$$

Equating the two expressions for Cos(θ') (6.2-8 and 6.2-9) and using equation 6.2-10 for Si;

$$1 - (\theta i')^2/2 = Ui/(Si' + \bar{S}). \qquad [6.2\text{-}11]$$

Solving for $(\theta i')^2$, one obtains;

$$(\theta i')^2 = 2 - 2Ui/\bar{S} - (\theta i')^2 Si'/\bar{S} + 2Si'/\bar{S}. \qquad [6.2\text{-}12]$$

Summing $(\theta i')^2$ over N samples and dividing by N yields the variance of θ. Note that the sum of the last term equals 0.

$$(\sigma(\theta))^2 = \sum_{i=1}^{N} (\theta i')^2/N = 2(1-\bar{U}/\bar{S}) - \sum_{i=1}^{N}((\theta i')^2 Si')/N\bar{S} \qquad [6.2\text{-}13]$$

The term, $\Sigma((\theta i')^2 Si')/N\bar{S}$, is 0 if the deviations in speed are uncorrelated with the deviation in direction. This assumption has been verified in tests on wind data by CSI; the Air Resources Laboratory, NOAA, Idaho Falls, ID; and MERDI, Butte, MT. In these tests, the maximum differences in

$$\sigma(\theta) = (\Sigma(\theta|')^2/N)^{1/2} \text{ and } \sigma(\theta) = (2(1 - \bar{U}/\bar{S}))^{1/2} \quad [6.2\text{-}14]$$

have never been greater than a few degrees. A2.5

The final form is arrived at by converting from radians to degrees (57.296 degrees/radian).

$$\sigma(\theta) = (2(1 - \bar{U}/\bar{S}))1/2 = 81(1 - \bar{U}/\bar{S})^{1/2} \quad [6.2\text{-}15]$$

Reviewers comments.

Six agencies returned reviews of the 12/97 draft of the report. In some cases more than one individual within the agency reviewed the report. These reviews are included in this section. Identifying information has been removed to protect the reviewers' anonymity. The reviews are assigned the letters A-F, particular comments are designated A1, A2, etc.

March 25, 1998

Dr. Bruce Johnson
Department of pesticide Regulation
Environmental Monitoring and Pest Management Branch
1020 "N" Street, Room 161
Sacramento, CA 95814-5624

Dear Bruce:

First, let me apologize for the long delay in getting comments back to you. The paper sat for about 1½ months before I realized that comments were due.

Second, let me apologize for the nature of the comments. This paper is just too deep in meteorology, so I struggled and so did Puttanna.

A

General comment: Add some more qualitative explanations, background, amplification of results/conclusions, etc — in short anything you can to help the reader know what you are doing at each stage, why it's important, and whether the associations are significant or not. Right now, it is hard to follow, and particularly so for one not skilled in the field of weather analysis. 1

Another general comment: The level of detail is outstanding, and the approach is the best that could be done given the nature of the task.

I wish you had access to fog and cloud cover data. Perhaps in the conclusion section you could recommend better data collection on these two parameters, particularly in fog-prone areas. 2

Finally, I personally feel that you have proved that any unusual weather conditions in Lompoc are not a cause of excessive exposure. If there is higher exposure, it will be due to pesticide usage — amounts, types, timing, method of application, proximity of fields to populace, etc. 3

Thanks for the opportunity to review this. Please send us a copy after it is finalized. And thanks very much for your review of Puttanna's paper.

Best regards,

comments. Specific comm and questions are in the text.

## Comments on Bruce Johnson's paper.

A3.2

1. Air quality model simulation work requires 10 m height (surface) met data, and when that is not available then any other available data is used. In case of Lompoc surface met data is readily available which should be compared against other surface met station data available from the coastal region. In the event surface met data is not available then CIMIS met data needs to be extrapolated to 10 m height for comparison. In your case there are more CIMIS station than Lompoc stations, so the Lompoc stations could be interpolated to 2 m height and then compared. 4 (A)

2. In my opinion the comparison of met data must be confined to the months when maximum number of applications take place in the Lompoc urban/agricultural interface as large data (annual) when subjected to rigors of statistics tend to camouflage the true nuances (seasonal differences) present in the data. 5

3. ISC-ST3 model runs were performed for one field of 10 acres and the receptor grid encompassed ~4 sq. miles. During a peak agricultural season there is certainly more than one field in a 4 sq. mile area getting treated with agricultural chemicals. Hence a multiple field scenario should be considered for model simulation. 6

4. Further, the rate of emission of 1 $\mu g/m^2/s$ used in your ISC-ST3 model simulation may not be representative. Yates et al (1996) measured 240 $\mu g/m^2/s$ on the day of application of methyl bromide in Southern California where the temperatures are generally higher than in Northern California. Hence a higher emission rate should be employed for model simulation. Bruce, perhaps our flux emission estimates in Environ. Sci Tech (1997) would be helpful. (See enclosure) 7

5. It is not clear as to July of which year's met data was used for the ISC-ST3 model simulation. 8

6. All other comments are mentioned in the paper.

Add: ~~Area map~~ Topo maps 9
Fog data (or at least more common "
Cloud cover ("

Bruce Johnson
Dept. Pesticide Regulation - EMPM
1020 N St. Rm 161
Sacramento, CA 95814-5624

Dear Bruce:

I've finally had a chance to look at your very thorough report- overall a very impressive job.

Major General Points:

Although you've done a nice job of using two possible mixing heights, the problem remains in determining the actual mixing heights at Lompoc and environs. Some data which might help might exist from some folks here in Oak Ridge, at ATDD/NOAA, who did a Vandenberg study recently, I think not too far from Lompoc. They may have actual mixing height data coupled with surface data in their micrometeorological study. At night, as the inversion builds, the value can be very low, and then as the convective boundary layer builds in the morning, the height rapidly increases, frequently to more than 1 km. Pesticide spraying tends to be in the early morning, but outgassing and rafting on particulates would be occurring at later times in the day, and eventually at night. B 1

I like the normalized flux stuff for concentration, but one could put in a very crude estimate of the outgassing fluxes from a field for a particular pesticide, from the literature, and then use this as an example of what the values would be under those conditions. Politically could be problematic, I suppose, if someone tried to misuse the numbers, but could also illustrate any potential problem or lack thereof—if you qualified the example carefully, it probably would be more helpful than harmful. 2

Also, on the issue of height and wind speed, in fact some accounting for wind speeds differences can be crudely done using the log-linear or power wind profile assumptions, as a first guess, for neutrality, but since you're estimating stability based on sigma theta, you could also even put in the appropriate coefficients for stability—you also have to guess at the type of surface to get a roughness height and length of the log-linear method (which meteorologists tend to use), and similar factors for the power law profiles (which engineers tend to use). If you need some help with this, I can probably send you some equations. For a typical grass canopy, for example, the log-linear profiles is:

$u = 2.5u^*(\log[(z-d)/zo])$, where d and zo are roughness parameters, approx. 0.67 and 0.1 times the roughness element heights for plant ecosystems, for example; $u^*$ is the friction velocity. For two different heights, over the same roughness type, the equation becomes 3
$u1/u2=\log[(z1-d)/zo]/\log[(z2-d)/zo] = \log[(z1-.67hc)/.1hc]/\log[(z2-.67hc)/.1hc$. For grass with a 10 cm height (hc), for example, your 2 m to 10 m difference translates to a 31% difference, i.e. the 10 m height will be approx. 1/3 greater than the 2 m height (note all logs here are actually ln, i.e., log base e), or conversely, the Lompoc stations should have their wind speeds reduced by multiplication be a factor of approx. 0.76 to match the CIMIS stations. This would tend to change your stability statistics for Lompoc

stations based on the EPA algorithm, since the lower wind speeds result in more stable conditions in the algorithm.

B

A3.4

Net radiation estimates, which come from CIMIS short-wave radiation data, can be used in stability estimates also. Did you investigate using any of those algorithms, to compare with the sigma theta method you used? 4

It would be useful to show a wind rose for the two Lompoc stations, and in addition, one the rose, the application frequency in those directions if the AUI's refer to areas with a specific geographic relationship to Lompoc. This integration gives a better idea of the context of the analysis. 5

Your summary is generally very good, and you have done a very scientific job of noting the limitations of the report and things that would need to be done to improve a study of any possible Lompoc pesticide problems.

More Specific Points:

p4 Of course there is 'no evidence' in terms of smoking guns etc.—this is very difficult to obtain—but the residents probably are pointing to things they see as 'evidence' and would be angered by the 'no evidence' statement. I would qualify this in terms of this wording: 'Although no detailed scientific (including biomedical) studies have shown...' The next sentence is very speculative, also...how do you know that the particular pesticides aren't important also? Obviously if only ivory soap was being used, the residents would not be concerned, while if anthrax and mustard gas are being used, they would be somewhat concerned. Why not just say that meteorology is important, but pesticide type and source strength are also important? Isn't this true? Then just say this study is to examine one aspect, the met. aspect, but other information would be relevant also (and if DPR is planning more work on the other aspects, refer to it here). 6

p.5 and elsewhere. It should be made clear somewhere in this document that the CIMIS net radiation estimates come from a short-wave, visible light sensor and the net radiation is estimated based on empirical regression equations. Therefore, all net radiation references should say 'estimates' and not 'data' because the sensor isn't even close to a net radiometer, it measures only visible light, and only the photo flux density which is then converted to energy assuming clear sky conditions. 7

p.5 The cup starting speed of 0.22 m/s sounds somewhat low. What type of cup did they have? Most start at 0.4-0.5 m/s when new, and higher as they age. 8

p.5 You might mentioned you started out looking at 14 stations,i.e., actually mention the number 14, such as ...'selecting all stations (14) that were near...' 9

p.7 Some data from Dr. Hanna and others show that sometimes, high sigma thetas occur under very stable conditions and low wind speeds, so in some cases using sigma theta would underestimate very stable conditions, because they would be identified by the algorithm you give as unstable or neutral. However, one might argue that sigma theta in itself is the variable to use for horizontal dispersion—but since you don't have vertical spread, stability is used for vertical spread, which would be important at the higher mixing heights (but less important at very low mixing heights, where you're trapping everything). The possibility of underestimation of very stable conditions should be noted here. 10

p.8 the issue of vane stalls should be noted in the context of low winds. This could result in reported values which are too low or too high. My own analysis (very brief, not definitive) shows in general, you expect values reported which are too high, because the vane sticks and then changes wildly to a new location when the intermittent gusts/meanders come along, with no values in between. The standard 11

deviation of a large change (weighted by the variances, so squares) is counted more heavily than the standard deviation of a small change.

p.8.9, elsewhere. The issue of logging frequency and averaging frequency should be discussed, unless I missed it. This can change the reported standard deviations also. 12

P13 It should be made more clear here that the "flux" you talk about is an "efflux", that is, an emitted flux of pesticide. The equation you present is essentially the deposition/source resistance, or the inverse of the deposition velocity vd. However, explicit mention of efflux and emissions will help clarify how the normalized concentration values are to be used—and an example would be even better—i.e., suppose 2 ug/m2s were being emitted, the values in fig.//table nn would have to multiplied by 2 to give you the concentration... 13

B

A3.5

p.13 I would emphasize the simulation picture more strongly here, perhaps even including a cartoon/figure showing the idealized probably flat terrain and source field. IN words, I would emphasize that this is the pesticide source area in the field, and that weather DATA from the stations are then used in the this same idealized field site to see where the pesticide goes, if effluxed from an area source of this dimension at height zero. Some note should also be made that conditions would be different if the source were higher (sometimes lower concentrations might be present at person /receptor height). Otherwise, right now it almost appears as if you've run the simulation for different sites centered at the stations; in reality you've used one site geometry, but different weather data gathered from different sites. 14

p.13 You should give some idea as to the conditions leading to the mixing heights you chose; for example, the 10 m height would be common during certain nocturnal conditions, while the 300 m height would be uncommon then, and be more likely during mid-morning conditions and later afternoon, during the strange convective boundary layer breakdown period. 15

P15. As noted elsewhere, mph should also have m/s with it, one in parentheses, consistently through the report. 16

P19: It is unclear why HSP is used for one table/figure, but H st for the other. Why not include both in each figure? Since Lompoc is really important, if you want to keep the same number of figures per page, omit one of the farther CIMIS stations which are not likely to be as important in this analysis as the Lompoc stations. 17

P21 What is AUI? Are these just number of applications, how about some idea of the pesticide loading, which would be related to the efflux and drift rates? 18

p.22 It's not clear why you're using latitude and distance in the stability regression. Why do you expect stability to be a function of these variables? You should forward some hypothesis about this, otherwise there is no reason to choose these variables, even if the regression comes out significant. 19

P23 and elsewhere. Sometimes m/s are used, and others, mph. Perhaps both should always be mentioned, the m/s for the scientific community, and the mph in parentheses for the general public. 20

P27: Based on the wind speed correction method noted earlier, the biases of wind heights CAN be crudely factored out, so your sentence here isn't really true. The roughness factors for buildings (which I did not use in the calc earlier) can be inserted into the 2 m versus 10 m heights to make a crude correction. Clearly, 10 m height winds are greater. You also should mention here, not only that crude corrections can be made, but that the stability estimated is dependent on this correction, so currently you have underestimated very stable conditions (just based on this factor, overall other factors may compensate OR make add to the underestimation—you have to consider things carefully). The issue of urbanization is 21

generally considered to scale with log of city population, so you can get some idea of the comparison between Louisville and Lompoc based on the logs of their populations.

p.27/28. Your statement here appears contradictory. First you say that the one can't say that one Lompoc station is more representative than the other (most objective scientists would agree with this, until more data on the valley compared to the Lompoc stations are gathered), and then you say HSP can apply, implying that it is better than H st. Since one doesn't know, one should advocate use of both stations' data, or the 'worst' of the two stations to be conservative. 22

p.30 the air pollution meteorology of drift, once already present, cannot be different than that for other pollutant releases: i.e., a cloud disperses from turbulence and mean wind advection in the same manner, irrespective of where it originates. Therefore, more stable conditions allow a more concentrated amount of material to occur, but this will impact a smaller horizontal area—if you're not near the centerline of the cloud, you're safer, but if you in the centerline region, you're more exposed. Unstable conditions spread the stuff out, so that if you're further cross wind, you are MORE exposed than under stable conditions, while if you're immediately downwind, you're LESS exposed. Part of the conservation of mass. Deposition is different from exposure, at least for prompt inhalation issues; for surface contact contamination and re-emissions after deposition, then deposition itself is important also. 23

B

P31 Your summary about the modest effects, of Lompoc compared to the CIMIS stations, is a little misleading—you have carried out a general study, with general climatology; but the spraying issue and pesticide problem, if existing, would be most likely from cumulative, episodic exposures relating to applications and outgassing during problematic meteorological conditions,coupled with high levels of sources of the pesticides. Also the model you used rather crudely deals with terrain effects, and it is not clear if you used terrain effects in the simulation. Terrain effects (mesoscale flow patterns) can greatly alter the results of a simulation, sometimes concentrating things greatly, other times dispersing things greatly—one can only tell by actually putting in the topographical forcing. This issue should be mentioned here. In addition the source location/receptor location and wind rose is another big issue in this type of study—something separate from the CIMIS stations data. From the wind rose for Lompoc, does the wind frequently flow form pesticide source areas? You do note that it does, but perhaps more emphasis with the % of time from these areas would help the public understand the issue. 24

Fig. 2: You should white out "current" because the date is October 1991; or white-out October 1991, instead, otherwise in 1998 the data appears old, and not current. 25

Appendices: I believe the CR-21X algorithm for std. Deviation, which you include as an appendix, is the Yamartino algorithm, which you should cite directly. The source of your photocopy, the CR-21X or 7X manual, should be cited also. The EPA citation is in the text, but not in the appendix, should be there also. 26

March 18, 1998

Mr. Bruce Johnson
California Environmental Protection Agency
Environmental Monitoring and Pest Mgmt. Branch
1020 N Street, Room 161
Sacramento, CA 95814-5624

Re: Comments on Draft of Study 153: Analysis of Lompoc Weather Patterns

Dear Bruce:

The comments of the first reviewer reflect more my understanding of the comparisons that were made in the report. I am not a modeler and my first reviewer is not a modeler either. He is a meteorologist like myself. My second reviewer is a modeler. We discussed the report and the techniques employed in quite a bit of depth. Although the second review seems a bit critical, he is very passionate in how he analyses things, and I did not want to edit his thoughts. He really is not trying to be negative, but rather that was his thought process in understanding your paper. In later discussions, it was he who helped me to better understand where you were going and that it was not just statistics for statistics sake. In our further discussions, he illuminated me about modeling and statistical techniques that I was not aware of before and to what you were actually doing and why. Your methods in the new light of understanding seem appropriate. The thing that the three of us agreed upon that should be done to help clarify the report is to better define why you chose the particular CIMIS stations used in this comparison (your assumptions), make sure that the abstract (I would call it an executive summary) and the conclusion sections agree (there are discrepancies), and, in the introduction, talk a bit about why you are doing this type of comparison and it's significance.

Sincerely,

# COMMENTS ON STUDY 153: ANALYSIS OF LOMPOC WEATHER PATTERNS REPORT

## First Reviewer

1. The analysis of Lompoc weather patterns would benefit from a map detailing the location of the two Lompoc sites, the general topography surrounding the Lompoc Valley, and the topography around the sites. The report should contain a discussion of the general effect that topography and terrain can have on each of the sites. In addition, the report should contain a discussion of general synoptic and mesoscale weather events that typically effect the meteorological conditions at the sites, such as marine layer inversions and seasonal prevailing winds. Comparison of actual meteorological data with these general descriptions would provide meaningful insight by either confirming expected measurements or highlighting unique deviations from the expected. 4 5

2. The report never discusses exactly why the comparisons with the 11 CIMIS sites are being performed. Without this information, any conclusions from the report are weak. For example, is the comparison being performed on the premise that the CIMIS sites are similar in nature to the Lompoc sites (climatology, topography, land use, surrounding population) but have no pesticide related problems? Without providing more detailed information about the CIMIS sites and their relationship to the Lompoc issues, it may be difficult for the report reader to determine the relevance of the comparisons. 6

3. If commonalties between the Lompoc and CIMIS sites do not exist, simply verifying that there are inherent differences between the Lompoc sites and other coastal sites may not be particularly informative. If this is the case, it would seem that concentrating on the Lompoc results, particularly the model runs, would be most useful. Statistical comparisons between the two Lompoc sites would demonstrate any diversity in the meteorology within the valley. 7

4. In general, the reasons for each of the statistical comparisons performed for this study should be described in detail so that readers of the report can better interpret the study findings. The reasons for the following were not clear:

- Why mixing heights of 300 and 10 meters where chosen. 8
- Regarding the pesticide use report data, the significance of the Turkey test for multiple means is not clear. How does the statistical significance of pesticide usage differences affect the report findings? 9

## Second Reviewer

1. Why compare met data with 11 other stations? 10

- Because other stations did no receive complaint?
- Studies performed at other stations indicate no significant exposure?
- Wanted to compare to other stations to see if Lompoc seemed unusual and knew that it would seem unusual if compared to non-coastal stations?

10 cont'd

2. In general the claim of statistically significant differences would seem unfounded when compared to known and/or expected variations in the measured parameters. I must admit that I do not understand all the statistical methods used, however, looking at figure 3 as an example:

- The error bars are much larger than any differences. 11
- The CMIS data, an average of 11 stations shows smooth curves by month following expected seasonal variations. The Lompoc station was much more erratic as would be expected from a single non-averaged station. I would like to see non-averaged CMIS data to see if the range of data for CMIS stations is larger than the differences as compared to Lompoc (i.e., all noise, no information). 12

3. In terms of modeled concentrations (slightly closer to end effect, health risk), differences as large as 32% are seen for the month displaying the largest difference in F stability classes. Not a huge difference for the most extreme example. Not expected to result in epidemiologicaly noticeable differences. The 32% increase was in the 90$^{th}$% bin for the monthly mean. Note that the 50$^{th}$% bin showed a 73% decrease (not mentioned in abstract or results section). 13

C

4. In general I believe the study demonstrated that met conditions vary from site to site. No general trend was shown.

| | Hsp | H St |
|---|---|---|
| F Class | + | 0 |
| Wind Persistence | - | + |
| Wind Speed | - | - |
| Modeling | 0 | +- |

+ indicates tendency toward greater exposure
- indicates tendency toward lesser exposure
0 indicates no significant difference

14

5. As can be seen, the only parameter for which both Lompoc stations agree is wind speed which would tend to lessen exposure. In general no consistency is seen between the two stations that are meant to be representative of the area of concern as compared to "normalizing stations." 15

6. The one parameter I would focus on would be wind direction persistence and which direction the winds blow compared to source/receptor combination. 16

DATE: March 6, 1998

SUBJECT: COMMENTS ON DRAFT "ANALYSIS OF LOMPOC WEATHER PATTERNS"

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At your request, we reviewed your draft report "Analysis of Lompoc Weather Patterns." Staff of our Modeling Support Section also reviewed the draft report (comments enclosed). Overall, we found the approach used in comparing meteorological data from Lompoc to other coastal stations to be acceptable. We have the following comments:

D

1. The report is titled "Study 153: Analysis of Lompoc Weather Patterns." We understand that "Study 153" refers to an internal Department of Pesticide Regulation (DPR) report number. You may want to make "Study 153" a subtitle and note that this is a DPR or branch report number. 1

2. We recommend that you include a table of contents. 2

3. On page 5, the text states that "Santa Maria is on a similar longitude as Lompoc." Since you are comparing net solar radiation data between Santa Maria and Lompoc, we recommend restating that Santa Maria is on a similar "latitude" as Lompoc. 3

4. We recommend that the following citations be included in the list of references:

   a. on pages 5, 11, and 28, Sikorski, personal communication; and

   b. on page 5, Eching, personal communication.

5. On Figure 2, we recommend that you note (e.g., by shading) the CIMIS stations used in the comparison to make them more easily distinguished from other CIMIS stations on the map.

6. On page 8, equations 2 and 3 are numbered out of order.

7. On the bottom of page 14, the text states that "hourly wind directions were tabulated into 45 dividing the 360 range of possible directions into 8 bins. We recommend that you restate this as tabulated into "45° groupings."

8. On page 29, the text states that "with regard to potential impact on air concentrations of pesticides fluxing from a field, more wind generally decreases air concentrations . . ." due to dilution. However, wind at the surface can also enhance the "wick effect," increasing diffusion into the air from a soil or leaf surface. You may want to note the counteracting effects of the wind.

9. In Table 6, it is unclear to what the "a," "ab," and "abc" refer. We recommend that this be clarified.

SUBJECT: DPR REPORT ON ANALYSIS OF LOMPOC WEATHER PATTERNS (STUDY 153)

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I have reviewed the above DPR report. The author utilized an acceptable EPA approach to compare and evaluate winds measured at different locations. Based upon my review, I offer the following comments.

1. I do not believe that the HSP site is representative of the Lompoc area because this site is located on higher terrain and north of the valley. The difference in geographic settings makes it inappropriate to use this site as a representative valley monitoring station. I would expect the stability, wind persistence, and direction to be different between the two stations. In fact, looking at the predicted concentration fields for the two sites as shown in Figures 6 and 7, it suggests that the wind directions for the HSP site are more variable than the wind direction at the H Street site, which shows a persistent west-northwest wind direction. I would expect the H Street site to behave this way because the Lompoc Valley being oriented in that direction. I recommend that DPR exclude the HSP site when comparing meteorological conditions to the Lompoc Valley. Until additional monitors are installed, the H street site would be the only representative station in the valley.

A3.13

2. DPR used data from CIMIS stations located along the coast from Monterey to San Diego to compare the stability conditions with that of Lompoc Valley. I question whether it is technically justifiable to compare the Lompoc station with other CIMIS stations of such widely varying climatic conditions along the Pacific Ocean. For example, the CIMIS stations in San Diego are influenced by a warmer Ocean current than those CIMIS stations located in the Monterey and Salinas Valley areas. Perhaps a narrower range of latitude in central California for CIMIS stations should be used in the comparison analysis. 12 D

3. Table 2 presents the useable versus non-useable days used in the analysis. The document should provide an explanation of how these terms were derived. Also, it is not documented in the report if the missing data occurred during the daytime or nighttime hours and how this may possibly lead to a bias in the stability analysis from deleting these values. 13

Dr. Bruce Johnson
Senior Environmental Research Scientist
Environmental Monitoring and Pest Management Branch
Environmental Protection Agency
Department of Pesticide Regulation
1012 N Street, Room 161
Sacramento, CA 95814-5624

Dear Dr. Johnson:

E

Thank you for the opportunity to review Study 153: Analysis of Lompoc Weadther Patterns.

In general, the methods for analyzing and comparing the wind statistics for the two Lompoc area stations appear quite thorough and complete.

However on pg. 12, bottom, it reads "...significantly greater fraction of F stability,...". greater than what? 1

On pg. 13 near bottom, what is "ISCST3." Where did it come from? 2

Very end of pg. 14-pg. 15 "...tabulating into 45 dividing the 360 rnage of..." 45 what? 360 what? 3

"Results" pg 16. Why compare the two Lompoc stations to the AVERAGE of the 11 CIMIS stations? After all the work to ensure the validity and confidence levels of all the Lompoc data, are these results are then compared with a statistic(s) for a number of stations; without necessarily knowing the validity or representiveness of these numbers (completely homogenous sample)? 4

**********

While on pg.4. at the end of the Introduction it is stated that "The purpose of the evaluation is to determime if meteorological patterns in Lompoc differ from patterns in other coastal sites in ways which would be likely to increase the presence of pesticides in the air." all that is done is the generation of some statistics from the surface wind data at two locations. This hardly represents a "meteorological (i.e., in this case climatological) study of the Lompoc Basin. 5

On the other hand, the Studies' conclusion is extremely astute: "The statistical analysis indicates patterns of meteorology which compared to the eleven coastal CIMIS stations indicates trends which could lead to higher concentrations of pesticides in the air, either from drift or outgassing following application."

Attached are excerpts from:

a) Atmospheric Diffusion, Pasquill, A. and Smith, F. B., Ellis Horwood,Ltd..
b) Meteorology, Miller, Albert, Merrill Books, Inc..
c) "Protocol for Analyzing Lompoc Weather Patterns," California Department of Pesticide Regulation.

In the "Protocol...," please note the grievous change in the stability class being discussed in the last paragraph of pg. 2, i.e., from meteorological stability which includes the thermal structure of the atmosphere to one of winds only. And from then on "stability" is "wind stability" only. But this in not meteorological stability. 6

Miller's discussions of stability in Meteorology, pgs 58-61, all include thermal/density considerations. E

Perhaps most noteworthy of all are Pasquill's own statements in Atmospheric Diffusion. On pg 312, "Because of the clear association between diffusive action and the thermal stability of the atmosphere, temperature gradient was adopted from the beginning as the main indicator, and much effort has been expended in many countries towards obtaining and maintaining current measurements of this quantity." 7

And finally on pg 341,
"The most urgent requirements are:
(a) ABANDONING OF THE QUALITATIVE STABILITY CATEGORIES IN TABLE 6.V....

Overall I think you have done a good job of analyzing the available wind data; and recognizing the limitations involved.

Thank you again for this opportunity. Please keep me informed (sorry I took so long this time).

Note: Appendix pages A3.16 to A3.25 were removed from the printed report due to copyright restrictions. Reviewer E referenced and included these pages in his review, which consisted of photocopies of selected pages from Atmospheric Diffusion by Pasquill et al. and Meteorology by Miller and Books. [B.Johnson]

# PROTOCOL FOR ANALYZING LOMPOC WEATHER PATTERNS

A3.26

1. Background

a. The use of pesticides in agricultural areas close to urban dwellings is controversial as urban residents have become more concerned about pesticides in the air, soil, and water, and about the effectiveness of regulatory restrictions in protecting citizens from pesticide exposure.

Citizens in the city of Lompoc, Santa Barbara County, have brought their concerns about use of agricultural pesticides to the forefront. Since late 1993, the Santa Barbara County Agricultural Commissioner's Office has received written complaints from Lompoc residents about pesticide use near their town. They have attributed health problems to pesticide use and have expressed concern about exposure to agricultural chemicals which were being carried from fields as a result of local weather conditions. A constant concern raised by the community is that the local weather patterns (*i.e.*, wind, fog, inversions) result in high exposure to pesticides. Although there is no well-defined health problem, and no evidence that specific pesticides are posing a risk to public health in the Lompoc area, the Department of Pesticide Regulation (DPR) is proposing a variety of approaches and activities in the agricultural/urban interface to promote reduced-risk pest management practices. We believe that the underlying factor for determining whether residents in Lompoc are highly exposed to pesticides is based more on the local weather pattern than particular pesticides being used. Therefore, an evaluation of the weather patterns in the Lompoc Valley needs to be done.

b. High pesticide concentrations in the air may result from two different kinds of processes: **outgassing** following application or direct spray **drift** occurring from aerial applications. From a technical perspective, these two processes are governed by different meteorological parameters.

i. High pesticide air concentrations from **outgassing** could result when either/or outgassing rates are high and meteorological conditions are stable. When meteorological conditions are stable, vertical mixing is reduced and plumes tend to remain cohesive, with high pesticide concentrations. During unstable meteorological conditions, vertical and lateral mixing reduce the concentration of pesticides within the downwind plume.

See p.58 Meteorology

(1) Another phenomenon which could contribute to high air

stable condition

concentrations is the presence of **low altitude inversion layers**. While it would be desirable to characterize the presence of low level inversion layers, the histor meteorological data does not contain the necess information to support such a determination. A3.27

ii. The second process, **drift** from spray, is thought to be minimized during wind speeds between 2-10 mph (U.S. EPA, 1995). [redacted]

c. Purpose

i. It is the overall aim of this study to delineate time periods when conditions might favor high concentrations of pesticides from outgassing or when conditions might favor drift due to wind speeds being outside the 2-10 mph zone. The purpose is to determine whether meteorological conditions in Lompoc uniquely favor weather conditions which could result in higher than average air concentrations or drift conditions. In this Phase 1 study, the product will be primarily a statistical summary of the relevant meteorological data. A Phase 2 project may be conducted which would utilize the Industrial Source Complex Short Term model to further study the potential for air concentrations under adverse conditions (Wagner, 1987).

2. Objectives

a. Examine the weather patterns in Lompoc Valley to determine if there are periods of time when pesticide applications might result in higher ambient pesticide concentrations.

DIFFERENT tabilities !!

i. For outgassing, this analysis is based on the U.S. EPA procedure for determining meteorological stability class (temperature) (U.S. EPA, 1986). Air concentrations are generally higher under stable, compared to unstable, air conditions due to greater vertical mixing during the unstable conditions. In addition, recent draft guidelines for minimizing spray drift suggest that drift is minimized if application can be made when wind speed is between 2-10 mph (U.S. EPA, 1995). By obtaining meteorological data from Lompoc, and classifying the hours into the appropriate stability class, (winds) seasonal trends in stability can be determined.

2 March 1998

Review of "Study 153: Analysis of Lompoc Weather Patterns" A3.28

author: Bruce R. Johnson. Dept of Pesticide Regulation. Sacramento. California

Summary of Recommendations: Recommend a second stability class calculation which does not depend upon sigma theta. at least for a sanity check. Recommend study of material flux dependence on wind speed and other environmental factors. Recommend using concentration and./or dosage for model comparison. Recommend study of toxicological effects of materials.

Itemized Comments:

1) p.6 "Computation of stability class". This is a logical algorithm for determining stability class, but you fail to note which. I assume it is the well-know "Pasquill-Gifford". If so, state it. There are others. 1

F

2) p.7 eq. 1 State the sampling frequency and averaging time, if you can find it. 2

3) p.8 "Calc. of standard deviation". It is VERY important to match the averaging time for the sigma theta measurements to that intended by the EPA stability class algorithm. Sigma theta is highly dependent upon averaging time. It's difficult to convert from one to another, but there are some crude methods. As you've shown here and elsewhere, the technique for estimating sigma theta is not important until you get over 20 degrees or so. However, it's good you have looked into that issue. 3

4) p.13 "Computer simulation ....". Did I miss it, or did you supply a reference for ISCST3. This report REALLY needs a model discussion. At least give the basics; model type (numerical/analytical), physics (including aerosol physics and any chemistry). 4

5) eq. 10. C/F is a funny number to use. You need to look at how the flux behaves with wind speed.. I'd guess the flux increases with wind speed. The model equations aren't supplied, but I believe if you would use U*C/F you may end up with a non-dimensional quantity which counteracts this effect. If your intention is to show concentrations, then plot concentrations. While it is probably not explicitly defined in the model F probably also is dependent on other factors, such surface temperature, which could have important implications when making recommendations. 5

6) p.16 "Comparison ... F stability", Fig. 3. These are higher percentages than I would expect. You never actually show the sigma theta's that you have calculated, but I'm guessing they are too low. You may not be matching averaging times to the stability class algorithm (see comment 3). I'd also prefer to see an alternate method which does not use sigma theta. You should be able to find a method which uses radiation and wind speed alone, at least to show your results are reasonable. 6

7) p. 18 "Computer simulation..". To reemphasize comment 5), you need to consider concentrations and/or dosages. You can scale the problem up or down with flux and field size. When it comes to effects on people, I've usually seen regulations related to either maximum concentrations (e.g. the class F cases in this document), or longer term exposures (dosages), .e.g. an average concentration over a 24 hour period. The dosage question is messy because you need to consider when the material is sprayed, and how the flux changes with time. 7

8) p. 21 "Station data". Not meteorologically sound. Suggest omitting this section. 8

9) p. 23 "Wind persistence analysis". This points to the fields with the potentially greatest impact on Lompoc. 9

10) "Discussion. " It may be beyond the scope of this report, but at some point the issue of toxicology needs to be addressed to consider recommendations. I've talked a bit about peak concentration vs dosage. The state of the material also needs to be consider; i.e. is the material more hazardous in aerosol form or gaseous? The recommendations will be dependent upon these criteria. 10

F

Response to reviewers comments.

This portion of the appendix contains my responses to the comments. In some cases, portions of the report were changed in response to reviewers' comments. In other cases, I have attempted to explain why I did not change the report. This portion of the appendix is intended to provide readers with some additional insight into the certainty and fidelity of the conclusions contained in the report, as expressed by the various reviewers.

The reviewer comments are numbered within each review and are located in section 3 of the Appendix. For example, A2, refers to the second comment by reviewer A. My responses to the comments are correspondingly numbered. In some cases, where more than one reviewer raised the same issue, my response is cross referenced.

A. Reviewer A

1. Will add clarifying language and comments. Other reviewers have made more specific suggestions on clarification.
2. Suggestion noted here.
3. I do not agree with this assessment because (1) the higher percentage of F stability in the HSP station may lead to higher air concentrations and this paper did not quantify the effect on drift (2) wind directions in the H St. station are notably consistent, from the NW (3) lack of information on low mixing height frequencies, which could be different in Lompoc than at other comparative coastal locations.
4. See B3.
5. I do not agree. There is no loss to making comparison in months besides the high use months.
6. Purpose in modeling was not to accurately estimate air concentrations. Purpose was to provide illustrative example of comparative effects of stability/wind persistence differences on modeling results and hence, on what levels of effect could be expected in the real world due to any differences which I found between Lompoc stations and CIMIS stations. Early comments made on very preliminary draft indicated that simply presenting statistical differences in frequency of F stability was incomprehensible. As a result, the suggestion was made to perform modeling to 'interpret' those statistical differences. In addition, I have tried to indicate that the modeling performed in this work only addresses the air concentrations which result from ground level revolatilization of pesticides. This modeling does not attempt to quantify down wind drift processes, which may result from aerial, or possibly, ground spray operations.
7. I am aware of paper referred to in comment. However, as noted just above in A6, this simulation was not intended to provide realistic absolute air concentration estimates. It was intended to compare the Lompoc results to the CIMIS results in terms of percentage impact. Consequently, there was no need to use a specific flux value that would represent a particular pesticide. As you know, the air concentrations which result from the ISCST3 model embody a proportionality between flux and air concentration. Hence, using the same flux in both the CIMIS and Lompoc simulations was the only requirement. I choose a flux that was convenient, namely 1 ug/m2s.
8. All usable July days from every year were used in simulation. Wording amended in methods to reflect this.

B. Reviewer B

1. While I have made some efforts towards acquiring mixing height data, the only data which is available derives from upper air soundings taken at Vandenberg AFB. The important issue is the relevance of such measurements to the Lompoc Valley. I am convinced that the only way to resolve the issue of mixing heights and low level inversions is to take measurements in the Lompoc Valley, not far from the City of Lompoc. The basis for this belief is contained in Skupniewicz et al. (1991) and Skupniewicz (1994), which detail differences between adjacent cloud covered and clear sky areas in the Lompoc Valley. As outlined in these papers, a typical diurnal cycle in this area consists of nighttime formation of a stratocumulus cloud deck, extending inland and reaching maximum inland coverage during the night. In the morning, heating from the sun raises the clouds until they dissipate. This burning off process proceeds from east to west and competing effects may result in a quasi stationary cloud front, in which Lompoc City is under clear skies, while the coast and some portion of the western Lompoc Valley is under cloud cover. With sunset and consequent loss of solar heating, the cloud deck lowers and again extends farther inland.

   A variety of measurements were made and presented indicating the differences between clear-sky and cloudy conditions, which may well exist simultaneously in the Lompoc Valley (Skupniewicz et al. 1991, Skupniewicz 1994). These measurements indicate differences between the two situations which lead me to believe that coastal measurements, such as the upper air data taken at VAFB cannot be reliably used to gauge the meteorology in the Lompoc Valley near the City of Lompoc. Some of the differences noted include heat flux and mixing layer height. During noontime surface flux in October was measured at approximately 0.07 C m/s compared to approximately 0.18 C m/s under cloudy versus clear conditions (Skupniewicz et al., 1991 Figure 4). Two of three transects across the cloudy-clear transition zone indicated elevated mixing heights under the clear sky, compared to cloudy condition (Skupniewizc et al. 1991 Figure 7). Skupniewicz (1994) calculates two plume growth factors, one for each zone, cloudy and clear. For these reasons, I believe the only reliable way to resolve issues about mixing heights or inversion heights is to take measurements of mixing height in the Lompoc Valley.
2. The scope of the modeling was described in A6 and A7. Attempting realistic estimates falls outside that scope.
3. To respond to this criticism, I took the equations from reviewer B and performed a small sensitivity analysis to determine how much the surface roughness influenced the resulting 'adjustment factor.' Table B3.1, below, indicates that the adjustment factor is robust to changes in the vegetation height from 5 to 50 cm. Z0 is calculated from Szeicz et al. (1969) and is the roughness parameter in cm. The equation is $\log(z0)=\log(H)-0.98$, where H is the crop height in cm. D is the zero plane displacement (cm) and is based on $\log(D)=0.979\log(H)-0.154$, given by Stanhill (1969). Finally u2/u10, uses the equation given by reviewer B to express the ratio of wind speed at 2 meters to wind speed at 10 meters. However, I have substituted the above expressions for calculating z0 and D, instead of reviewer's estimate which was .67H and 0.1H, respectively.

**Table B3.1 Change in the adjustment factor as a function of changing the vegetation height.**

| Height(cm) | Z0 | D | u2/u10 | u10/u2 |
|---|---|---|---|---|
| 5 | 0.52 | 3.39 | 0.79 | 1.27 |
| 10 | 1.05 | 6.68 | 0.76 | 1.32 |
| 15 | 1.57 | 9.94 | 0.74 | 1.35 |
| 20 | 2.09 | 13.17 | 0.73 | 1.37 |
| 30 | 3.14 | 19.59 | 0.70 | 1.43 |
| 40 | 4.19 | 25.97 | 0.68 | 1.47 |
| 50 | 5.23 | 32.31 | 0.66 | 1.52 |

It is important that the adjustment factor not be too sensitive to differences in vegetation height; otherwise, making adjustments without more specific site information would be dubious. Although the DWR has attempted to follow consistent siting criteria for the CIMIS stations, they are clear in stating that this is not always possible. The CIMIS web site states: "Many of the weather stations sites in the CIMIS network are not the ideal large pasture situation. Some of these stations do not meet all of the above siting criteria." (Department of Water Resources 1998). However, even with consistent siting criteria, there may be differences in pasture height.

Since the adjustment factor appeared to be fairly robust, however, it seemed reasonable to recalculate the stability classes based on increasing the CIMIS wind speeds by a factor of 1.31, as derived by reviewer B. The expectation would be that increasing the wind speeds to adjust for the 2m measurement height, would generally cause less stable conditions to occur. Consequently, the overall summary statistics for CIMIS stations would show lower mean percentages of F stability, and thereby, potentially allow for more statistically significant results when used to compare against the Lompoc station results. The program used to estimate stability classes for the CIMIS stations was modified to increase the windspeed by a factor of 1.31. Then the stability classes for the CIMIS stations were determined as before.

The result of this reevaluation of F stability is shown in Table B3.2.

**Table B3.2 Recalculation of CIMIS F stability frequencies after increasing the wind speed by 1.31 to adjust for 2m measurement height.**

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 19.5 | 27.2 | 27.5 | 29.1 | 25.8 | 25.6 | 28.5 | 33.1 | 38.8 | 40.2 | 32.1 | 22.9 | 28.1 |
| 19 | 20.8 | 22.7 | 24.7 | 21.3 | 15.3 | 14.4 | 19.3 | 23.7 | 29.8 | 35.5 | 30.7 | 28.0 | 23.8 |
| 49 | 44.4 | 41.5 | 38.0 | 34.5 | 31.0 | 27.6 | 30.2 | 31.7 | 34.4 | 40.9 | 45.4 | 50.9 | 37.5 |
| 52 | 44.4 | 41.1 | 37.4 | 29.4 | 30.8 | 26.4 | 29.0 | 32.5 | 34.6 | 38.7 | 40.3 | 46.0 | 35.9 |
| 64 | 46.5 | 40.2 | 38.6 | 35.2 | 33.2 | 30.2 | 30.5 | 32.9 | 37.2 | 44.5 | 47.5 | 50.6 | 38.9 |
| 66 | 34.8 | 31.6 | 25.9 | 26.8 | 28.3 | 27.4 | 29.7 | 33.4 | 32.1 | 33.2 | 35.2 | 36.5 | 31.2 |
| 94 | 34.6 | 33.9 | 30.3 | 25.3 | 26.5 | 22.2 | 24.9 | 25.6 | 29.5 | 36.0 | 40.5 | 40.1 | 30.7 |
| 95 | 31.9 | 26.9 | 30.8 | 24.5 | 20.6 | 19.9 | 24.3 | 27.4 | 35.2 | 36.5 | 37.4 | 32.7 | 29.2 |
| 97 | 31.9 | 31.0 | 33.6 | 31.9 | 30.6 | 28.1 | 28.8 | 33.2 | 35.3 | 40.1 | 33.4 | 30.9 | 32.4 |
| 102 | 42.5 | 39.4 | 35.0 | 31.6 | 29.3 | 25.5 | 27.7 | 31.6 | 33.0 | 39.7 | 41.8 | 44.3 | 35.0 |
| 104 | 26.2 | 25.8 | 26.2 | 20.5 | 24.4 | 19.6 | 23.3 | 23.1 | 26.2 | 22.6 | 25.7 | 32.6 | 24.8 |
| Avg | 34.3 | 32.8 | 31.6 | 28.2 | 26.9 | 24.3 | 26.9 | 29.8 | 33.3 | 37.1 | 37.3 | 37.8 | 31.6 |
| SD | 9.5 | 6.8 | 5.2 | 5.0 | 5.2 | 4.7 | 3.5 | 4.1 | 3.7 | 5.7 | 6.6 | 9.3 | |
| SEM | 2.9 | 2.1 | 1.6 | 1.5 | 1.6 | 1.4 | 1.1 | 1.2 | 1.1 | 1.7 | 2.0 | 2.8 | |
| L(0.99893) | 22.6 | 24.4 | 25.2 | 22.0 | 20.4 | 18.5 | 22.6 | 24.8 | 28.7 | 30.0 | 29.1 | 26.2 | |
| U(0.99893) | 46.0 | 41.3 | 38.0 | 34.3 | 33.4 | 30.1 | 31.3 | 34.9 | 37.8 | 44.1 | 45.4 | 49.3 | |
| H St. | 36.1 | 36.3 | 33.3 | 28.9 | 29.2 | 26.2 | 27.7 | 32.1 | 35.1 | 40.0 | 44.0 | 47.0 | 34.7 |
| HSP | 33.1 | 31.7 | 29.6 | 29.5 | 30.4 | 28.4 | **33.5** | **36.1** | **38.7** | 37.8 | 36.2 | 38.5 | 33.6 |
| | | | | | | | sig | sig | sig | | | | |

The result of these calculations, as expected, decreased the frequency of F stability for the CIMIS stations. The overall frequency decreased from 32.9% (From Table 3 of report) to 31.6%. This was a relatively minor change, and when the confidence intervals were recalculated, the same pattern emerged in the statistical comparison as with the unadjusted comparisons. H St. exhibited no significant differences, whereas July, August, and September in the HSP station were statistically greater than the average CIMIS stations, as in Table 3.

Therefore, adjusting for the height at which the wind speed was measured did not affect the comparison of fraction of F stability.

4. This goes beyond the scope of the study, which as outlined in the protocol, assumes the fidelity of the Pasquill-Gifford method based on horizontal standard deviation for determining stability conditions.
5. Wind rose diagrams for both stations added onto figure from Akers et al. (1995) and explanatory text added in wind persistence section. This is Figure 10.
6. Wording amended.

7. Reviewer is correct. Text amended. The CIMIS procedure utilizes a pyranometer in conjunction with empirically based equations to estimate net solar radiation (Dong et al. 1988), based on a theoretical equation found in Monteith (1973).
8. The name of the anemometer is MET 1 010B and I confirmed the performance characteristics with APC personnel (Sikorski, personal communication).
9. Wording amended.
10. Wording amended and Hanna (1983) reference cited.
11. I'm not convinced that your analysis is uniformly correct. The factors determining the variability will be the length of time between changes in the position and the distribution of positions. If there are 2 vane positions during a one hour period, then most of the 1 second samples will be identical (there will be only 2 direction values for the 3600 measurements) and the variance will be very low. However, if there are many wild jumps during the hour, then the variance will be higher. So, whether vane stall situation increases or decreases variance in relation to a vane with a zero threshold would depend on the frequency of the stalls and as well as on the distribution of positions.
12. The CIMIS loggers take one instantaneous sample per minute and base the hourly standard deviation calculation on the 60 samples, while the two meteorological stations in Lompoc take one sample per second, then perform a standard deviation calculation every minute, finally averaging the 60 one minute standard deviations to estimate the hourly standard deviation. The simulation results indicated some differences between the ability of these two methodologies to estimate the true standard deviation. However, these differences had no practical effect on the statistical analysis of fraction of F stability. A potential weakness in the simulation was the use of Gaussian noise for simulating the wind speeds and directions since Gaussian noise contains no autocorrelational structure. In contrast, for example, variation of wind parameters is viewed in Pasquill and Smith (1983, p.25) as a composition of sinusoidal components. However, it is beyond the scope of this report to attempt more complex simulations using spectrally structured noise.
13. Wording amended.
14. Wording amended.
15. Wording amended.
16. Additional units added as suggested.
17. Comparison of the two Lompoc stations as a separate objective was beyond the scope of this report. Such comparisons are of natural interest because these two stations have been represented as spanning the range of conditions in the Lompoc Valley. This statement, which is based on personal observations by local SBAPCD personnel, has been taken at face value and it has not been an objective of this study to determine the truth or falseness of that statement. In order to properly assess that statement, a number of weather stations would have to be set up in the Lompoc Valley and the data would have to be examined in relation to the HSP and H St. stations to determine if HSP and H St. stations could be said to represent the range of conditions in the valley. This is clearly beyond the scope of this study. These two stations are shown on separate pages because the statistical comparisons are

all between either the HSP station or the H St. station and the 11 CIMIS stations. The statistical comparisons are generally not between the HSP and H St. stations.

18. The AUI are agricultural urban interface sections. The draft failed to define this acronym. The acronym is now defined in the Methods section under subheader Use Report Data. The AUI concept for Lompoc was defined in Akers et al. (1995) and is related to those agricultural sections which border the City of Lompoc along the west and north edges.
19. Based on B19 and F8 this statistical analysis section is deleted.
20. See B16.
21. See B3.
22. Wording amended.
23. I agree generally with your comments. However, it seems that, in general, pesticide drift has been much more difficult to quantify, model and understand. Perhaps the best effort in this regard would be actual monitoring in Lompoc, which would represent the integration of all effects, known and unknown.
24. I did not use terrain effects in simulation and I have added language clarifying this. The purpose of the simulation was very simple, to get a handle on the likely magnitude of the effect on concentration that the stability index differences would have. The reason for undertaking the simulation was because the stability index itself was very difficult to interpret in other than a qualitative way. The purpose of the simulation was not to provide definitive, accurate estimates of air concentrations arising from realistic scenarios. I have added the wind rose and some discussion regarding the location of agriculture and wind direction in relation to the City of Lompoc
25. The 1991 map was used to select the stations. So I have presented it here. I have used arrows to show where the eleven CIMIS stations used in this report are located.
26. According to DWR personnel, the CIMIS stations actually use the 'Campbell Scientific algorithm', the discussion of which was included in the draft appendix. The actual text of that discussion is no longer available in Campbell Scientific manuals and my efforts to obtain further documentation and background from Campbell Scientific failed. The xeroxed pages represent pages from Campbell Scientific 21X Operators Manual Revision: 21X.OM 2/87. When the Yamartino (Yamartino 1984) algorithm became available on the Campbell data loggers, the CIMIS station managers made the decision to stay with the Campbell algorithm to preserve consistency. Newer manuals omit the discussion of the Campbell Scientific method, but present the equations for the algorithm. The simulation work which I did in the report indicates that the Campbell Scientific algorithm provides satisfactory results for standard deviations smaller than 25 degrees, which is adequate for the comparative purposes in this report.

C. Reviewer C

1. The Introduction states that a purpose was to compare Lompoc to other coastal stations. The particular stations chosen were relatively close to the coast. Given that there were relatively few stations to choose from, I did not wish to exclude stations. See discussion in C6 below.

2. I have reviewed the abstract and summary for discrepancies.
3. Wording amended.
4. Topographic map showing site locations now included.
5. Section entitled 'Regional Climatology' added
6. No assumptions have been made concerning the presence or absence of pesticide related problems for either the Lompoc or CIMIS station areas. The study is attempting to determine if there are measurable differences between historical Lompoc weather station records and historical CIMIS station records which might lead to higher concentrations of pesticides in the Lompoc area. The main criteria, as mentioned elsewhere, for selecting the CIMIS stations was a general proximity near the Pacific Ocean because the Lompoc station weather is dominated by proximity to the ocean.
7. On the contrary, verifying differences between the Lompoc and other sites, where such differences imply possible enhancement of air concentrations of pesticides, would provide a basis for further investigation, such as monitoring. In contrast, statistical comparison of the two Lompoc sites, would not be particularly informative and goes beyond the scope of the project.
8. See B15, wording amended.
9. The Tukey test is used for multiple means comparisons (Steel and Torie 1960). It attempts to compensate for the phenomenon that when many means are compared, spurious significant differences will be found more frequently. It provides a conservative procedure to gauge how big mean differences need to be before they become significant. I have added more explanation to the Table caption for this table to make it clearer.
10. The goal was to compare Lompoc stations to other coastal stations to determine if weather patterns in Lompoc might contribute to increasing air concentrations of pesticides in comparison to other coastal sites.
11. The reviewer misunderstands the purpose and comparisons indicated in Figure 3. The reviewer has commented as though months are being compared to each other. In fact, the comparison is within each month, between the average of the CIMIS stations and each of the two Lompoc stations. The error bars are confidence intervals around the mean CIMIS station value for that month. The empty symbols represent the Lompoc stations. If either of the Lompoc station symbols lies outside of the confidence interval, that connotes a significant difference between that Lompoc station and the average of the CIMIS stations.
12. Non-averaged data was presented in Table 3.
13. Noted.
14. The reviewer's table appropriately summarize the findings with the possible exception of HSP modeling. I would characterize that as +-. Since, however, the two stations were taken to represent the range of conditions within the valley, and since the degree to which each station is representative of the valley has not been established, the prudent outlook is to take the most conservative of each comparison in the reviewer's table. Thus, taking the most conservative of the two stations results in the following modified reviewer table:

| | HSP | H St. | Result |
|---|---|---|---|
| F Class | + | 0 | + |
| Wind Pers. | - | + | + |
| Wind Speed | - | - | - |
| Modeling | 0 | +- | +- |

Using this outlook, there does appear to be some evidence for enhancement of pesticide air concentrations based solely on the wind/stability analysis in this report. See A3.

15. See C14.
16. Noted.

D. Reviewer D

1. Amended.
2. Table of contents added.
3. The intention of using the net solar radiation is to gauge when sunshine starts and stops because this has a large affect on the stability class. The magnitude of the solar radiation itself is not used, only the sign (positive or negative). Consequently, the relevant consideration is longitude, not latitude.
4. Fixed.
5. Fixed.
6. Station map uses arrows to indicate relevant CIMIS stations.
7. Fixed, thank you.
8. Fixed, thank you.
9. See F5
10. See C9.
11. See B17.
12. Given the methodology of using statistical procedures as a basis for comparing the two Lompoc stations to the CIMIS stations, it was desirable to include as many stations as seemed to fit the description of coastal stations. While important differences in a variety of geographical, climatic or other kinds of factors may be offered as a basis for excluding certain stations from the study, it was precisely to determine if some distinct features emerged amongst the Lompoc stations in comparison to other coastal stations that this study was undertaken. For example, should all coastal CIMIS stations that are not in valleys be excluded since perhaps they would not be similar enough to the Lompoc stations? The answer is no, because, in part, if the valley has a unique influence on the Lompoc meteorology, then perhaps that would explain any unusual findings and that is what we wish to find out. In addition, the sample size is not really large enough to exclude stations. The sample represents a fairly full exposition of the kinds of conditions that arise along the California coast in agricultural areas. These range of conditions had to be characterized in order to provide a basis for comparison with the Lompoc stations.
13. The paragraph 'Missing Values' in the Methods section explains the definition of unusable days. I have rewritten this section to make it more clear. When more than 4 values were missing during a day from either wind direction, wind speed, standard deviation of wind direction, temperature or net radiation, then the whole day was omitted. Therefore, no biases would be introduced with regard to night hours versus daytime hours being excluded.

E. Reviewer E

1. Wording amended.
2. Additional explanation of ISCST3 added.
3. Clarified 45 degrees.
4. The validity or representativeness of the CIMIS station numbers stems from (1) the manner in which the data is collected (2) the concept or population that they are supposed to represent. With regard to (1), the CIMIS stations have extensive QA/QC and include QA/QC flags with the data sets. CIMIS station data is collected in a consistent and repeatable fashion and I believe this data is reliable. With regard to (2), the population which this data is supposed to represent is the weather along the coast in agricultural areas. That is weather amongst marine dominated stations in agricultural areas. The CIMIS stations are located in agricultural areas because their purpose is to provide irrigation guidance. They probably represent the only set of stations that reasonably reflects this concept. It's possible with only 11 stations that some bias is present with respect to the meteorology amongst all agricultural locations in marine dominated coastal areas. However, there is not much that could be done about any such bias, save for eliminating stations from the CIMIS pool, which as I've indicated in C12 is not desirable because the sample size is already small.

5. Webster's Seventh New Collegiate Dictionary (1970) defines meteorology:

   1. A science that deals with the atmosphere and its phenomena and esp. with weather and weather forecasting
   2. The atmospheric phenomena and weather of a region.

   Perhaps given the restricted question being addressed (are there factors in the weather which might lead to enhanced air concentrations of pesticides in relation to other coastal sites) and given the restricted data available (i.e. localized mixing height not available for Lompoc Valley or CIMIS stations, fog and overcast data not available, etc.), it is overstating it to call this a 'meteorological' study. Reviewer is correct in that primarily this analysis utilizes surface wind data to reach its conclusions.
6. The intent in the Protocol was the same as in the study, namely to use surface wind measurements to gauge stability according to the Pasquill Gifford scheme. Reviewer is correct in pointing out that there is a difference between stability as thermal structure or stability as 'wind stability'. It would extremely desirable to obtain vertical temperature profiles for the Lompoc Valley because in addition to assessing stability, the mixing height could also be determined. Unfortunately, there are no data sets available which provide hourly vertical thermal structure in Lompoc, which can be used effectively to assess stability in the Lompoc Valley. Therefore, the wind stability scheme of Pasquill and Gifford is used as a proxy.
7. Reviewer partially quotes from Pasquill and Smith (1983). The full quotation here is:

(a) abandoning of the qualitative stability categories in Table 6.V in favor of the parameters H0, u*, L and w*, for which there is now a reasonable prospect of specification in terms of routine meteorological data (see Section 6.2).

Table 6.V referred to by the above quotation utilizes stability categories A-F, but the algorithm embodied by Table 6.V is different from that used in this work in that it depends on degree of insolation during the day and overcast at night, both in conjunction with wind speed to determine stability class. This is different than the algorithm in this work, which depends on the standard deviation of the horizontal wind direction in conjunction with night versus day and wind speed.

The data recorded by the SBAPCD and the data recorded by CIMIS stations do not permit calculation of the parameters mentioned in the paragraph above. Indeed, in Section 6.2 of Pasquill and Smith (1983), it is stated that the routine measurements that are required are an estimate of z0, together '...with measurements of the low-level wind speed and of the temperature difference between two low levels.' (P.313) The latter measurement, temperature at two low levels, does not exist for the CIMIS or Lompoc stations. Therefore, while for many reasons it may be desirable to abandon the qualitative stability categories A-F, there are no other options in this study.

F. Reviewer F

1. Wording amended to reflect that this is Pasquill stability class scheme.
2. Text amended to include these details.
3. Text now includes these details and see B12.
4. Additional descriptive language added and refs, USEPA (1995ab).
5. The original idea for normalizing the concentrations by flux stemmed, as explained in the report, from the linear relationship between flux and concentration. However, at least one author has also utilized this normalization procedure (Skupniewicz 1994, p.643 equations 6 and 9, Figure 4). The units of the normalized in Skupniewicz (1994) values are time/volume because the source flux, Q, is in units of mass/time, in contrast to my report where the source flux is area normalized and the units are mass/time-area. This explains the difference in normalized units as found in Skupniewicz (1994) and in my paper. Nevertheless, the concept is the same.

   Turner (1994) defines C/F (X/Q in his notation, p.A-2) as relative concentration and CU/F (Xu/Q in his notation, p.A-2) as relative concentration normalized for wind speed. Perhaps my use of the phrase 'normalized concentration' is confusing with regard to Turner's definitions. In Turner's notation, and since ISCST modeling has historically been oriented toward industrial stack releases, the units for Q are mass/time (g/s, usually). In Turner's plots of relative concentration normalized for wind speed, the resulting units are m-2 (reciprocal meter squared). In the case of area sources, the units are more appropriately mass/area-time. When these area source units are used for flux (Q or F in the above

expressions), then CU/F would be non dimensional. As discussed in my paper, C/F is reciprocal velocity, or resistance (time/distance). I have added explanatory language to the text in order to clarify that if a flux rate is known, then expressing that flux rate in units of ug/m2-s, enables one to multiply the isopleths in the simulation results by that flux rate to convert to concentration. I have tried to stay away from estimating actual concentrations because the purpose of this simulation was to gauge the comparative effect of the different F stability frequencies on concentration. The purpose was not to estimate an actual air concentration.

There is no convenient way to estimate CU/F given that modeling was being conducted with actual, time varying meteorological measurements in which both wind direction and wind speed changed each hour. However, since flux was constant, it was possible to model with unit flux and thereby obtain C/F.

The reviewer makes the point that flux might be related to wind speed. There is theoretical basis for the notion that flux increases with increasing wind speed (Jenkins et al. 1993). One of the factors thought to control flux is diffusion through a boundary layer (Spencer and Cliath 1973, Jury et al. 1980). In the case of soil applied materials, the boundary layer would be adjacent to the soil. Jury et al. (1983, p.562) assign a default value of 2.5mm to the width of this stagnant air layer. In the case of foliar applied materials, the boundary layer might consist of small regions around leaves and stems, or in the case of well developed canopy, the entire structure of the canopy. For leaves, Nobel (1974, p.306) presents an equation for the boundary layer depth indicating that the depth is proportional to the inverse square root of wind speed. Thus doubling of wind speed reduces the boundary layer distance by a factor of $2^{-1/2}$ . Using Fick's Law with flux inversely proportional to distance, this represents a potential flux increase by a factor of $2^{1/2} = 1.4$, or 40% increase from a leaf surface. A similar concept could probably be applied to canopy resistance. Woodrow et al. (1986) and Hsieh et al. (1995) develop and discuss addition of a multiplicative adjustment term, (1+3u), where u is the wind speed in m/s, to estimates of volatilization rates from plant surfaces. Hsieh et al. (1995) suggest that the coefficient of three probably depends on the heat of vaporization of the compound. The suggestion by Hsieh et al. (1995), however, is preliminary and requires more work to verify for actual plant canopies. In contrast to the potential for increasing wind speed to also increase flux, however, Cliath et al. (1980) found an opposite trend for soil surfaces. He found that under moist soil conditions, that wind caused a cooling effect at the soil surface, which led to mildly stable atmospheric conditions at the soil surface and, in turn, reduced flux of EPTC.

While in theory, increasing wind speed will decrease the effective width of soil, foliar, or canopy boundary layers and hence, decrease resistance and increase flux, other processes may be rate limiting for soil incorporated and soil applied materials. Materials with a low Henry's law number, tend to move through the soil with moisture and their flux rate depends

to a great degree on soil moisture and water evaporation rate (Glotfelty et al. 1984, Spencer and Cliath 1973, Spencer et al. 1988). When the soil dries out near the surface, flux may decrease significantly compared to when soil surface is moist and evaporation is taking place. In these cases, wind speed is a secondary effect. Temperature has also been shown to affect flux rates, either indirectly by affecting water evaporation or directly by changing the vapor pressure (Farmer et al. 1972).

I found several papers which published data containing both wind speed and corresponding flux measurements. To determine the possible effect of wind speed on flux from measured data, I regressed flux on wind speed or used published regressions. The results did not indicate a strong relationship in field studies. In the following table, specific units for F and W vary, but generally F is units of mass/time-area and W is linear distance/time.

| Equation | Significance | Study description | Data | Citation |
|---|---|---|---|---|
| F=155+0.015W | p=0.93, r2=0% | Dacthal, surface soil spray | Table 5, wind speed at 150cm, Table 4 AD flux | Majewski et al. 1991 |
| F=721-87.7W | p=.38, r2=7% | nitrapyrin, surface soil spray | Table 2, wind speed at 1 m, Table 3 AD-P flux | Majewski et al. 1990 |
| F=0.477-0.011W | p=.78, r2=0.2% | Triallate, surface soil spray | Data interpolated from Figures 3 and 4a (AG method) | Majewski et al. 1993 |
| F=-0.0013+0.0073W | p=.003, r2=57% | Diflufenican, , surface soil spray, outside wind chamber | Data interpolated from Figure 4 | Stork et al. (undated) |
| (authors calculations) | not significant | dieldrin, surface applied | authors report wind speed not significant in multiple regression | Willis et al. 1972 |

| | | | | |
|---|---|---|---|---|
| F=-0.92+0.4ln(W)-7.8ln(Ta)+8.6ln(Ts)<br><br>(Authors calculations) | wind speed, air and soil temp significant | data from Harper et al. 1976, Fig 5 trifluralin soil applied and incorporated | unclear how regression obtained since 'weather model' reference gives different form | Nash 1983<br><br>(my regression analysis leads to different conclusion) |
| log(W)=.52F-2.49 (note: authors regressed wind speed on flux) | P=.001 | dieldrin, from quartz sand and glass | Figure 9, wind speeds very low range, .0009-1.3m/s | Jenkins et al. 1993 |

In three cases there was a significant relationship (i.e. p<.05) between flux and wind speed. In Stork et al. (Undated), measurements were conducted at 2 controlled wind speeds, 1 and 2 m/s in a field chamber. In Jenkins et al. (1993) volatilization was from nonabsorbing surfaces in special chambers. In Nash (1983), the regression was based on field data from Harper et al. (1976). However, the form of the regression differs from the form in Nigg et al. (1977), which Nash terms the 'weather model' and cites as the theoretical basis for performing the regression. Thus, it is unclear how the regression was obtained. I interpolated flux, windspeed, air and soil temperature and soil moisture from Harper et al. (1976, Fig 5), the same figure cited by Nigg et al. (1977) as the basis for their calculations. A direct regression of flux on wind speed resulted in an r2 of 33% (p=.74). A multiple regression approach yielded soil temperature as the single, best explanatory model (r2=88%, p=.001). Adding any more of the other variables did not significantly improve the model.

The other studies, which were field studies, did not show a relationship between wind speed and flux. Unfortunately, I was unable to locate studies which measured flux from plant canopies.

I must conclude that although three studies suggest wind speed has the potential for influencing flux, there are other processes which appear to dominate in controlling flux values in field situations. Therefore, adjusting the normalized concentrations by wind speed in order to account for a presumed increase in flux does not seem warranted.

6. Reviewer mistakenly assumes in comment that I have calculated sigma thetas. The sigma thetas are calculated by the data loggers used in the respective meteorological stations. Data loggers in the two Lompoc stations use the ESC algorithm, while the CIMIS station data loggers use the 'Campbell Scientific equation'. These values are not calculated by me.

While it would be of interest to look at different schemes for calculating the stability class, that goes beyond the scope of

this work.

7. This comment suggests that I should estimate exposure. Although I agree that exposure estimates would be of great interest in this case, such an endeavor goes well beyond the scope of this report. In addition, I believe exposure estimates based only on meteorology and modeling calculations would be premature. Instead, exposure estimates should be tied to actual measurement of pesticide concentrations in Lompoc.
8. Section deleted.
9. Comment noted.
10. See F7.

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Peter M. Rooney
*Secretary for Environmental Protection*

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A5.1

MEMORANDUM

TO: Kean S. Goh, Ph.D., Agriculture Program Supervisor IV
Environmental Monitoring and
Pest Management Branch

FROM: Bruce Johnson, Ph.D., Senior Environmental Research Scientist
Environmental Monitoring and
Pest Management Branch
(916) 324-4106

DATE: December 8, 1998

SUBJECT: ESTIMATION OF AIR MONITORING VARIABILITY FROM 1807 STUDIES

Recently the question arose as to how large a 30 percent difference in simulated air concentrations is. I described the difference as modest. In the course of discussing that adjective, it became clear that use of the term "modest" was based on subjective impressions gathered over several years of reviewing various monitoring data. Therefore, in order to identify more clearly and objectively whether a 30 percent air concentration could reasonably be called modest, I undertook an analysis of 1807 air monitoring data.

**Methods.** The scope of 1807 studies which I used are defined by those listed in Kollman (1995). There have been several more studies added to the 1807 database since Kollman (1995). However, due to time constraints those additional studies were not analyzed. The 1807 data is generally of two different types: application site monitoring, in which monitoring periods range over several hours, and ambient monitoring, in which monitoring periods are usually 24 hours. Application site monitoring typically occurs near an application of the target material, and may last for several days, usually not longer than 7 days. Ambient monitoring takes place away from nearby applications, and will usually last for several days, sometimes spanning several weeks.

I have further divided the data into two categories: collocated and simultaneous. The collocated data consists of separate samples, taken from samplers in close proximity (usually about 2 meters) to each other for the same time period. The Air Resources Board protocols typically include collocated samplers in order to assess sampling variability. The simultaneous data consists of data from a series of samplers, which may be hundreds to thousands of meters apart, but for approximately the same time period. I have excluded data with non-detects. In cases containing collocated samples, I have taken the average value of the collocated samples to use for the simultaneous data.

For application monitoring, I have relied solely on the data as found in Kollman (1995), with the exception of molinate which required closer scrutiny of raw data tables to obtain concentrations. For ambient monitoring, I have read through and extracted the ambient monitoring data from the associated 1807 reports; the same used in Kollman (1995). For collocated data, I have listed on each row the collocated samples. In most cases this consists of two samples, although there were more than two in a few studies. For simultaneous data, I have listed on each row data taken at the same time. All of the data which I used can be found in Tables 1 and 2.

For each line of data, I have computed the mean, standard deviation, and coefficient of variation as a percentage. The coefficient of variation is the standard deviation divided by the mean (times 100 to obtain the percentage). The actual concentration units do not matter in calculating the coefficient of variation because the numerator (standard deviation) and denominator (mean) are in the same units and therefore, cancel. For application monitoring all concentrations are ug/m3 (Table 1). For ambient monitoring, I have indicated the concentration units which are not uniform between chemicals (Table 2). For each of the four combinations of application or ambient and collocated or simultaneous, I have calculated the arithmetic average or mean coefficient of variation and also the median ($50^{th}$ percentile) coefficient of variation.

**Results**. Table 1A shows the data and analysis for the application monitoring for collocated samples. The average coefficient of variation was 14.65 percent and the median was 6.53 percent. The median is lower than the mean because the median is not affected as much by skewing as is the mean. The CV percentages ranged from 0 to 101 percent. Table 1B shows the data used for calculating the coefficient of variation for simultaneous measurements. The coefficient of variations ranged from 9.64 percent to 176.37 percent. The average coefficient of variation was 85.21 percent and the median was 78.18 percent. One third of the values were greater than 100 percent. These values are naturally substantially higher than the collocated samples due to affects of wind, distance, sampler location, application differences, and other variables. In theory the variation of the simultaneous samples includes the sampling variation measured by the collocated samples. Thus variability in the simultaneous samples should be larger than variability in collocated samples.

Coefficient of variation for ambient values shows similar trends in comparing collocated to simultaneous measurement based values. The collocated values in Table 2A yielded an average coefficient of variation of 14.25 percent, with a median of 8.84 percent. The actual values ranged from 0 percent to 78.54 percent. The simultaneous values exhibited an average of 74.68 percent with a median of 67.11 percent (Table 2B). They ranged from 0 percent to 179.38 percent. As in the case of application monitoring, the simultaneous measurements yielded a higher average coefficient of variation than the collocated measurements.

The results are summarized in Table 3.

**Table 1A. Application 1807 monitoring -- collocated samples. All data from Kollman (1995)**

| | | | | | | Mean | SD | CV % | Sorted | | %tile |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.700 | 1.200 | azinphos-methyl | p.27 | app | ug/m3 | 1.4500 | 0.3536 | 24.38 | 0.00 | 1 | 1.9 |
| 0.490 | 0.860 | azinphos-methyl | p.27 | app | ug/m3 | 0.6750 | 0.2616 | 38.76 | 0.00 | 2 | 3.8 |
| 0.340 | 0.230 | carbofuran | p.42 | app | ug/m3 | 0.2850 | 0.0778 | 27.29 | 0.00 | 3 | 5.8 |
| 0.550 | 0.660 | carbofuran | p.42 | app | ug/m3 | 0.6050 | 0.0778 | 12.86 | 0.00 | 4 | 7.7 |
| 0.210 | 0.210 | carbofuran | p.42 | app | ug/m3 | 0.2100 | 0.0000 | 0.00 | 0.00 | 5 | 9.6 |
| 0.070 | 0.080 | carbofuran | p.42 | app | ug/m3 | 0.0750 | 0.0071 | 9.43 | 0.00 | 6 | 11.5 |
| 0.060 | 0.060 | carbofuran | p.42 | app | ug/m3 | 0.0600 | 0.0000 | 0.00 | 0.00 | 7 | 13.5 |
| 0.158 | 0.119 | chlorothalonil | p.47 | app | ug/m3 | 0.1385 | 0.0276 | 19.91 | 0.00 | 8 | 15.4 |
| 0.122 | 0.127 | chlorothalonil | p.47 | app | ug/m3 | 0.1245 | 0.0035 | 2.84 | 0.00 | 9 | 17.3 |
| 0.098 | 0.103 | chlorothalonil | p.47 | app | ug/m3 | 0.1005 | 0.0035 | 3.52 | 0.00 | 10 | 19.2 |
| 0.026 | 0.034 | chlorothalonil | p.47 | app | ug/m3 | 0.0300 | 0.0057 | 18.86 | 0.00 | 11 | 21.2 |
| 0.043 | 0.039 | chlorothalonil | p.47 | app | ug/m3 | 0.0410 | 0.0028 | 6.90 | 0.00 | 12 | 23.1 |
| 0.051 | 0.052 | chlorothalonil | p.47 | app | ug/m3 | 0.0515 | 0.0007 | 1.37 | 1.37 | 13 | 25.0 |
| 0.034 | 0.030 | chlorothalonil | p.47 | app | ug/m3 | 0.0320 | 0.0028 | 8.84 | 2.32 | 14 | 26.9 |
| 0.030 | 0.035 | chlorothalonil | p.47 | app | ug/m3 | 0.0325 | 0.0035 | 10.88 | 2.84 | 15 | 28.8 |
| 0.058 | 0.053 | chlorothalonil | p.47 | app | ug/m3 | 0.0555 | 0.0035 | 6.37 | 3.45 | 16 | 30.8 |
| 0.046 | 0.046 | chlorothalonil | p.47 | app | ug/m3 | 0.0460 | 0.0000 | 0.00 | 3.52 | 17 | 32.7 |
| 0.013 | 0.010 | chlorothalonil | p.47 | app | ug/m3 | 0.0115 | 0.0021 | 18.45 | 4.04 | 18 | 34.6 |
| 0.016 | 0.024 | chlorothalonil | p.47 | app | ug/m3 | 0.0200 | 0.0057 | 28.28 | 4.04 | 19 | 36.5 |
| 0.018 | 0.017 | chlorothalonil | p.47 | app | ug/m3 | 0.0175 | 0.0007 | 4.04 | 4.20 | 20 | 38.5 |
| 0.012 | 0.016 | chlorothalonil | p.47 | app | ug/m3 | 0.0140 | 0.0028 | 20.20 | 4.29 | 21 | 40.4 |
| 0.034 | 0.034 | chlorothalonil | p.47 | app | ug/m3 | 0.0340 | 0.0000 | 0.00 | 4.29 | 22 | 42.3 |
| 0.023 | 0.023 | chlorothalonil | p.47 | app | ug/m3 | 0.0230 | 0.0000 | 0.00 | 4.29 | 23 | 44.2 |
| 0.010 | 0.014 | chlorothalonil | p.47 | app | ug/m3 | 0.0120 | 0.0028 | 23.57 | 6.37 | 24 | 46.2 |
| 0.016 | 0.017 | chlorothalonil | p.47 | app | ug/m3 | 0.0165 | 0.0007 | 4.29 | 6.45 | 25 | 48.1 |
| 1.330 | 1.810 | mancozeb | p.55 | app | ug/m3 | 1.5700 | 0.3394 | 21.62 | 6.53 | 26 | 50.0 |
| 0.310 | 0.530 | mancozeb | p.55 | app | ug/m3 | 0.4200 | 0.1556 | 37.04 | 6.90 | 27 | 51.9 |
| 0.160 | 0.270 | mancozeb | p.55 | app | ug/m3 | 0.2150 | 0.0778 | 36.18 | 8.84 | 28 | 53.8 |
| 0.150 | 0.180 | mancozeb | p.55 | app | ug/m3 | 0.1650 | 0.0212 | 12.86 | 9.43 | 29 | 55.8 |
| 0.100 | 0.120 | mancozeb | p.55 | app | ug/m3 | 0.1100 | 0.0141 | 12.86 | 10.88 | 30 | 57.7 |
| 1.250 | 0.280 | methidathion | p.64 | app | ug/m3 | 0.7650 | 0.6859 | 89.66 | 12.86 | 31 | 59.6 |
| 0.600 | 0.100 | methidathion | p.64 | app | ug/m3 | 0.3500 | 0.3536 | 101.02 | 12.86 | 32 | 61.5 |
| 9.000 | 9.300 | molinate | p.78 | app | ug/m3 | 9.1500 | 0.2121 | 2.32 | 12.86 | 33 | 63.5 |
| 2.450 | 2.600 | molinate | p.78 | app | ug/m3 | 2.5250 | 0.1061 | 4.20 | 14.14 | 34 | 65.4 |
| 0.360 | 0.530 | molinate | p.78 | app | ug/m3 | 0.4450 | 0.1202 | 27.01 | 18.13 | 35 | 67.3 |
| 3.400 | 3.100 | molinate | p.78 | app | ug/m3 | 3.2500 | 0.2121 | 6.53 | 18.45 | 36 | 69.2 |
| 3.200 | 3.400 | molinate | p.78 | app | ug/m3 | 3.3000 | 0.1414 | 4.29 | 18.86 | 37 | 71.2 |
| 3.210 | 2.930 | naled | p.85 | app | ug/m3 | 3.0700 | 0.1980 | 6.45 | 19.91 | 38 | 73.1 |
| 0.340 | 0.440 | naled | p.85 | app | ug/m3 | 0.3900 | 0.0707 | 18.13 | 20.20 | 39 | 75.0 |
| 0.180 | 0.170 | naled | p.85 | app | ug/m3 | 0.1750 | 0.0071 | 4.04 | 21.62 | 40 | 76.9 |
| 0.050 | 0.030 | naled | p.85 | app | ug/m3 | 0.0400 | 0.0141 | 35.36 | 23.57 | 41 | 78.8 |
| 0.110 | 0.110 | naled | p.85 | app | ug/m3 | 0.1100 | 0.0000 | 0.00 | 24.38 | 42 | 80.8 |
| 0.160 | 0.170 | naled | p.85 | app | ug/m3 | 0.1650 | 0.0071 | 4.29 | 27.01 | 43 | 82.7 |
| 0.020 | 0.020 | naled | p.85 | app | ug/m3 | 0.0200 | 0.0000 | 0.00 | 27.29 | 44 | 84.6 |
| 0.420 | 0.400 | dichlorvos | p.87 | app | ug/m3 | 0.4100 | 0.0141 | 3.45 | 28.28 | 45 | 86.5 |
| 0.090 | 0.110 | dichlorvos | p.87 | app | ug/m3 | 0.1000 | 0.0141 | 14.14 | 29.18 | 46 | 88.5 |
| 0.060 | 0.060 | dichlorvos | p.87 | app | ug/m3 | 0.0600 | 0.0000 | 0.00 | 35.36 | 47 | 90.4 |
| 0.060 | 0.060 | dichlorvos | p.87 | app | ug/m3 | 0.0600 | 0.0000 | 0.00 | 36.18 | 48 | 92.3 |
| 0.090 | 0.090 | dichlorvos | p.87 | app | ug/m3 | 0.0900 | 0.0000 | 0.00 | 37.04 | 49 | 94.2 |
| 0.010 | 0.010 | dichlorvos | p.87 | app | ug/m3 | 0.0100 | 0.0000 | 0.00 | 38.76 | 50 | 96.2 |
| 0.400 | 0.400 | ziram | p.93 | app | ug/m3 | 0.4000 | 0.0000 | 0.00 | 89.66 | 51 | 98.1 |
| 0.038 | 0.025 | ziram | p.93 | app | ug/m3 | 0.0315 | 0.0092 | 29.18 | 101.02 | 52 | 100.0 |

**Average CV%** **14.65**

**Table 1B. Application 1807 monitoring -- simultaneous measurements (Data from Kollman 1995)**

| | | | | | Average | SD | CV% | Sorted | | %tile |
|---|---|---|---|---|---|---|---|---|---|---|
| Azinphos methyl | | 1994 p.27 | | | | | | | | |
| | 1.5 | 1.600 | 1.45 | 0.77 | 1.33 | 0.38 | 28.46 | 9.64 | 1 | 0.02 |
| Carbofuran | | 1994 p.42 | | | | | | 13.09 | 2 | 0.05 |
| | 0.21 | 0.030 | 0.075 | 0.11 | 0.11 | 0.08 | 72.02 | 20.84 | 3 | 0.07 |
| | 0.12 | 0.040 | 0.06 | 0.05 | 0.07 | 0.04 | 53.24 | 24.21 | 4 | 0.09 |
| Chlorothalonil | | 1992 p.47 | | | | | | 28.46 | 5 | 0.12 |
| | 0.03 | 0.012 | 0.034 | | 0.03 | 0.01 | 47.70 | 40.56 | 6 | 0.14 |
| | 0.041 | 0.020 | 0.023 | | 0.03 | 0.01 | 40.56 | 43.52 | 7 | 0.16 |
| | 0.052 | 0.018 | 0.012 | | 0.03 | 0.02 | 78.92 | 45.92 | 8 | 0.19 |
| | 0.032 | 0.014 | 0.017 | | 0.02 | 0.01 | 45.92 | 47.70 | 9 | 0.21 |
| Mancozeb | | 1993 p.55 | | | | | | 53.24 | 10 | 0.23 |
| | 0.2 | 0.250 | 0.165 | | 0.21 | 0.04 | 20.84 | 56.28 | 11 | 0.26 |
| MITC | | 1993 p.60 | | | | | | 58.86 | 12 | 0.28 |
| | 1.39 | 0.064 | 0.051 | | 0.50 | 0.77 | 153.36 | 58.86 | 13 | 0.30 |
| | 2.63 | 6.390 | 12.4 | | 7.14 | 4.93 | 69.02 | 61.89 | 14 | 0.33 |
| | 6.99 | 2.120 | 242 | | 83.70 | 137.11 | 163.81 | 63.70 | 15 | 0.35 |
| | 70.5 | 111.000 | 224 | | 135.17 | 79.55 | 58.86 | 69.02 | 16 | 0.37 |
| | 22.1 | 105.000 | 77.7 | | 68.27 | 42.25 | 61.89 | 71.90 | 17 | 0.40 |
| | 5.82 | 153.000 | 23.2 | | 60.67 | 80.43 | 132.56 | 72.02 | 18 | 0.42 |
| | 20.2 | 21.800 | 8.41 | | 16.80 | 7.31 | 43.52 | 73.98 | 19 | 0.44 |
| | 3.2 | 3.200 | 2.6 | 3.6 | 3.15 | 0.41 | 13.09 | 74.01 | 20 | 0.47 |
| | 2.3 | 1.500 | 6.5 | 2.3 | 3.15 | 2.26 | 71.90 | 77.43 | 21 | 0.49 |
| | 26 | 4.700 | 26 | 580 | 159.18 | 280.73 | 176.37 | 78.92 | 22 | 0.51 |
| | 3.9 | 2.400 | 26 | 120 | 38.08 | 55.67 | 146.22 | 82.66 | 23 | 0.53 |
| | 70 | 5.800 | 26 | 1.2 | 25.75 | 31.41 | 121.96 | 89.43 | 24 | 0.56 |
| | 800 | 100.000 | 250 | 200 | 337.50 | 314.58 | 93.21 | 90.31 | 25 | 0.58 |
| | 90 | 9.000 | 8.1 | 94 | 50.28 | 48.21 | 95.89 | 93.21 | 26 | 0.60 |
| | 51 | 120.000 | 8.6 | 1.2 | 45.20 | 54.48 | 120.53 | 95.89 | 27 | 0.63 |
| | 210 | 200.000 | 430 | 880 | 430.00 | 318.22 | 74.01 | 95.93 | 28 | 0.65 |
| Molinate | | 1992 p.78 | | | | | | 100.26 | 29 | 0.67 |
| | 9.17 | 2.480 | 0.45 | | 4.03 | 4.56 | 113.13 | 102.56 | 30 | 0.70 |
| | 11.3 | 0.370 | 0.27 | | 3.98 | 6.34 | 159.28 | 104.01 | 31 | 0.72 |
| | 10.1 | 0.590 | 2.65 | 0.57 | 3.48 | 4.52 | 130.02 | 113.13 | 32 | 0.74 |
| | 8.62 | 0.300 | 2.02 | 0.86 | 2.95 | 3.85 | 130.42 | 117.90 | 33 | 0.77 |
| | 0.35 | 0.450 | 6.77 | 2.62 | 2.55 | 3.00 | 117.90 | 120.53 | 34 | 0.79 |
| | 0.12 | 1.320 | 5.98 | 3.24 | 2.67 | 2.56 | 95.93 | 121.96 | 35 | 0.81 |
| Naled | | 1995 p.85 | | | | | | 130.02 | 36 | 0.84 |
| | 3.07 | 1.230 | 6.3 | 0.04 | 2.66 | 2.73 | 102.56 | 130.42 | 37 | 0.86 |
| | 0.39 | 0.090 | 0.85 | 0.07 | 0.35 | 0.36 | 104.01 | 132.56 | 38 | 0.88 |
| | 0.18 | 0.010 | 0.13 | 0.14 | 0.12 | 0.07 | 63.70 | 146.22 | 39 | 0.91 |
| | 0.11 | 0.860 | 2.16 | 0.45 | 0.90 | 0.90 | 100.26 | 153.36 | 40 | 0.93 |
| | 0.17 | 0.950 | 2.08 | 1.04 | 1.06 | 0.78 | 73.98 | 159.28 | 41 | 0.95 |
| | 0.02 | 0.140 | 0.25 | 0.09 | 0.13 | 0.10 | 77.43 | 163.81 | 42 | 0.98 |
| Dichlorvos | | 1995 p.87 | | | | | | 176.37 | 43 | 1.00 |
| | 0.41 | 0.130 | 0.51 | | 0.35 | 0.20 | 56.28 | | | |
| | 0.06 | 0.320 | 0.82 | 0.25 | 0.36 | 0.32 | 89.43 | | | |
| | 0.09 | 0.940 | 0.99 | 0.85 | 0.72 | 0.42 | 58.86 | | | |
| | 0.01 | 0.110 | 0.23 | 0.09 | 0.11 | 0.09 | 82.66 | | | |
| Ziram | | 1994 p.93 | | | | | | | | |
| | 1.69 | 0.146 | 2.26 | 0.4 | 1.12 | 1.02 | 90.31 | | | |
| | 0.072 | 0.051 | 0.077 | 0.05 | 0.06 | 0.01 | 24.21 | | | |
| | 0.037 | 0.031 | 0.032 | | 0.03 | 0.00 | 9.64 | | | |
| | | | | | **Average CV %** | | **85.21** | | | |

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| Table 2A. Ambient 1807 monitoring -- collocated samples | | | | | Mean | SD | CV % | Sorted | | %tile |
|---|---|---|---|---|---|---|---|---|---|---|
| Azinphos-methyl | ppt | | 1987 p.21 | | | | | | | |
| | 6 | 5.2 | 6.1 | 6.3 | 5.90 | 0.48 | 8.19 | 0.00 | 1 | 0.01 |
| | 2.9 | 2.4 | 2.8 | 2.6 | 2.68 | 0.22 | 8.29 | 0.00 | 2 | 0.01 |
| | 1.6 | 2.8 | | | 2.20 | 0.85 | 38.57 | 0.00 | 3 | 0.02 |
| | 1.9 | 1.8 | | | 1.85 | 0.07 | 3.82 | 0.00 | 4 | 0.03 |
| | 2.6 | 1.6 | | | 2.20 | 0.57 | 25.71 | 0.00 | 5 | 0.04 |
| | 2.3 | 2.3 | 2.7 | 2.2 | 2.38 | 0.22 | 9.34 | 0.00 | 6 | 0.04 |
| | 3.2 | 2.8 | | | 3.00 | 0.28 | 9.43 | 0.00 | 7 | 0.05 |
| | 1.3 | 1.3 | | | 1.30 | 0.00 | 0.00 | 0.00 | 8 | 0.06 |
| | 1.6 | 1.6 | 1.6 | 1.9 | 1.68 | 0.15 | 8.96 | 0.00 | 9 | 0.07 |
| | 1.9 | 1.9 | | | 1.90 | 0.00 | 0.00 | 0.00 | 10 | 0.07 |
| | 9 | 7.8 | | | 8.40 | 0.85 | 10.10 | 0.00 | 11 | 0.08 |
| | 1.6 | 1.6 | 1.6 | 1.6 | 1.60 | 0.00 | 0.00 | 0.00 | 12 | 0.09 |
| | 4.3 | 3.9 | | | 4.10 | 0.28 | 6.90 | 0.00 | 13 | 0.10 |
| | 1.9 | 1.6 | | | 1.75 | 0.21 | 12.12 | 0.00 | 14 | 0.10 |
| | 1.6 | 1.7 | | | 1.65 | 0.07 | 4.29 | 0.00 | 15 | 0.11 |
| | 2.8 | 3 | | | 2.90 | 0.14 | 4.88 | 0.00 | 16 | 0.12 |
| | 4.6 | 4.7 | | | 4.65 | 0.07 | 1.52 | 0.00 | 17 | 0.13 |
| Bromoxynil | ppt | | 1988 p - no page number | | | | | 0.00 | 18 | 0.13 |
| | 2.5 | 2.2 | | | 2.35 | 0.21 | 9.03 | 0.13 | 19 | 0.14 |
| | 1 | 1.5 | | | 1.25 | 0.35 | 28.28 | 0.65 | 20 | 0.15 |
| | 1 | 1.5 | | | 1.25 | 0.35 | 28.28 | 0.98 | 21 | 0.15 |
| | 3.5 | 3 | | | 3.25 | 0.35 | 10.88 | 1.05 | 22 | 0.16 |
| | 1.4 | 1.4 | | | 1.40 | 0.00 | 0.00 | 1.08 | 23 | 0.17 |
| Chloropicrin | ppt | | 1986 p23 | | | | | 1.52 | 24 | 0.18 |
| | 69.10 | 62.80 | | | 65.95 | 4.45 | 6.75 | 1.83 | 25 | 0.18 |
| | 61.00 | 62.60 | | | 61.80 | 1.13 | 1.83 | 2.11 | 26 | 0.19 |
| | 21.00 | 23.90 | | | 22.45 | 2.05 | 9.13 | 2.42 | 27 | 0.20 |
| | 64.10 | 40.30 | | | 52.20 | 16.83 | 32.24 | 2.48 | 28 | 0.21 |
| | 25.60 | 25.60 | 25.60 | | 25.60 | 0.00 | 0.00 | 2.61 | 29 | 0.21 |
| | 49.10 | 41.80 | | | 45.45 | 5.16 | 11.36 | 2.83 | 30 | 0.22 |
| | 28.60 | 39.70 | | | 34.15 | 7.85 | 22.98 | 2.97 | 31 | 0.23 |
| | 32.10 | 33.60 | | | 32.85 | 1.06 | 3.23 | 3.01 | 32 | 0.24 |
| | 14.60 | 14.60 | | | 14.60 | 0.00 | 0.00 | 3.03 | 33 | 0.24 |
| | 62.10 | 58.80 | | | 60.45 | 2.33 | 3.88 | 3.23 | 34 | 0.25 |
| | 38.40 | 51.50 | | | 44.95 | 9.26 | 20.61 | 3.29 | 35 | 0.26 |
| | 24.10 | 15.60 | | | 19.85 | 6.01 | 30.26 | 3.43 | 36 | 0.26 |
| | 40.40 | 33.70 | | | 37.05 | 4.74 | 12.79 | 3.57 | 37 | 0.27 |
| | 21.00 | 30.30 | 16.60 | | 22.63 | 6.99 | 30.90 | 3.82 | 38 | 0.28 |
| | 591.00 | 771.00 | | | 681.00 | 127.28 | 18.69 | 3.86 | 39 | 0.29 |
| | 242.00 | 317.00 | | | 279.50 | 53.03 | 18.97 | 3.97 | 40 | 0.29 |
| | 53.90 | 60.50 | | | 57.20 | 4.67 | 8.16 | 4.04 | 41 | 0.30 |
| | 268.00 | 268.00 | 37.60 | | 191.20 | 133.02 | 69.57 | 4.20 | 42 | 0.31 |
| | 101.00 | 91.00 | 107.00 | | 99.67 | 8.08 | 8.11 | 4.20 | 43 | 0.32 |
| Chlorothalonil | ppt | | 1990 p5 | | | | | 4.29 | 44 | 0.32 |
| | 0.51 | 0.45 | | | 0.48 | 0.04 | 8.84 | 4.81 | 45 | 0.33 |
| | 0.5 | 0.5 | | | 0.50 | 0.00 | 0.00 | 4.86 | 46 | 0.34 |
| Methidaoxon | ug/m3 | | 1991 no page # | | | | | 4.88 | 47 | 0.35 |
| | 0.061 | 0.058 | | | 0.06 | 0.00 | 3.57 | 4.96 | 48 | 0.35 |
| | 0.073 | 0.067 | | | 0.07 | 0.00 | 6.06 | 5.24 | 49 | 0.36 |
| | 0.048 | 0.077 | | | 0.06 | 0.02 | 32.81 | 5.24 | 50 | 0.37 |
| | 0.043 | 0.077 | | | 0.06 | 0.02 | 40.07 | 5.86 | 51 | 0.38 |
| | 0.11 | 0.097 | | | 0.10 | 0.01 | 8.88 | 5.89 | 52 | 0.38 |
| | 0.06 | 0.089 | | | 0.07 | 0.02 | 27.52 | 6.06 | 53 | 0.39 |
| Methidathion | ug/m3 | | 1991 no page # | | | | | 6.09 | 54 | 0.40 |
| | 0.023 | 0.024 | | | 0.02 | 0.00 | 3.01 | 6.34 | 55 | 0.40 |
| | 0.56 | 0.56 | | | 0.56 | 0.00 | 0.00 | 6.43 | 56 | 0.41 |
| | 0.29 | 0.32 | | | 0.31 | 0.02 | 6.96 | 6.75 | 57 | 0.42 |
| | 0.015 | 0.011 | | | 0.01 | 0.00 | 21.76 | 6.83 | 58 | 0.43 |
| | 0.098 | 0.042 | | | 0.07 | 0.04 | 56.57 | 6.90 | 59 | 0.43 |
| Methyl parathion | ng/m3 | | 1986 Table 9 | | | | | 6.96 | 60 | 0.44 |
| | 0.58 | 0.47 | | | 0.53 | 0.08 | 14.82 | 7.14 | 61 | 0.45 |
| | 1 | 1.09 | | | 1.05 | 0.06 | 6.09 | 7.26 | 62 | 0.46 |
| | 0.52 | 0.56 | | | 0.54 | 0.03 | 5.24 | 7.89 | 63 | 0.46 |
| | 1.09 | 1.1 | | | 1.10 | 0.01 | 0.65 | 8.11 | 64 | 0.47 |
| | 0.455 | 0.537 | | | 0.50 | 0.06 | 11.69 | 8.16 | 65 | 0.48 |
| | 0.73 | 0.7 | | | 0.72 | 0.02 | 2.97 | 8.19 | 66 | 0.49 |
| | 0.58 | 0.41 | | | 0.50 | 0.12 | 24.28 | 8.29 | 67 | 0.49 |
| | 0.47 | 0.52 | | | 0.50 | 0.04 | 7.14 | 8.84 | 68 | 0.50 |
| | 0.34 | 0.39 | | | 0.37 | 0.04 | 9.69 | 8.88 | 69 | 0.51 |
| | 4.47 | 7 | 8.49 | | 6.65 | 2.03 | 30.55 | 8.96 | 70 | 0.51 |
| | 22.2 | 24.7 | 30.1 | | 25.67 | 4.04 | 15.73 | 9.03 | 71 | 0.52 |
| | 20.1 | 21.3 | 23.2 | | 21.53 | 1.56 | 7.26 | 9.13 | 72 | 0.53 |
| | 12.4 | 14.1 | 14.9 | | 13.80 | 1.28 | 9.25 | 9.25 | 73 | 0.54 |
| | 14.5 | 15.2 | 15 | | 14.90 | 0.36 | 2.42 | 9.34 | 74 | 0.54 |
| | 5.52 | 5.48 | 4.02 | | 5.01 | 0.85 | 17.07 | 9.43 | 75 | 0.55 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 15.5 | 12 | 14.4 | 13.97 | 1.79 | 12.81 | 9.43 | 76 | 0.56 |
| | 8.57 | 8.8 | 7.8 | 7.72 | 0.89 | 11.49 | 9.89 | 77 | 0.57 |
| | 2.35 | 2.35 | 1.7 | 2.13 | 0.38 | 17.59 | 10.10 | 78 | 0.57 |
| | 4.74 | 4.98 | 7.46 | 5.73 | 1.51 | 26.30 | 10.88 | 79 | 0.58 |
| | 2.97 | 2.78 | 2.77 | 2.84 | 0.11 | 3.97 | 11.36 | 80 | 0.59 |
| | 1.31 | 1.83 | 1.15 | 1.43 | 0.36 | 24.86 | 11.49 | 81 | 0.60 |
| | 0.74 | 1.33 | | 1.04 | 0.42 | 40.31 | 11.69 | 82 | 0.60 |
| | 3.89 | 5.49 | | 4.69 | 1.13 | 24.12 | 11.85 | 83 | 0.61 |
| | 22.8 | 20.7 | | 21.75 | 1.48 | 6.83 | 12.12 | 84 | 0.62 |
| | 5.39 | 5.72 | | 5.56 | 0.23 | 4.20 | 12.73 | 85 | 0.63 |
| | 5.3 | 5.31 | | 5.31 | 0.01 | 0.13 | 12.79 | 86 | 0.63 |
| | 5.69 | 4.75 | | 5.22 | 0.66 | 12.73 | 12.81 | 87 | 0.64 |
| | 4.77 | 4.7 | | 4.74 | 0.05 | 1.05 | 13.73 | 88 | 0.65 |
| | 1.48 | 1.41 | | 1.45 | 0.05 | 3.43 | 14.60 | 89 | 0.65 |
| | 1.18 | 1.5 | | 1.34 | 0.23 | 16.89 | 14.82 | 90 | 0.66 |
| | 1.6 | 2.04 | | 1.82 | 0.31 | 17.09 | 15.73 | 91 | 0.67 |
| | 0.69 | 0.63 | | 0.66 | 0.04 | 6.43 | 16.89 | 92 | 0.68 |
| | 0.34 | 0.33 | | 0.34 | 0.01 | 2.11 | 17.07 | 93 | 0.68 |
| Methyl paraoxon | ng/m3 | | 1986 Table 13 | | | | 17.09 | 94 | 0.69 |
| | 1.8 | 2.5 | 2.65 | 2.32 | 0.45 | 19.58 | 17.59 | 95 | 0.70 |
| | 0.53 | 0.85 | 1.1 | 0.83 | 0.29 | 34.56 | 17.83 | 96 | 0.71 |
| | 7.79 | 0.5 | 6.91 | 5.07 | 3.98 | 78.54 | 18.69 | 97 | 0.71 |
| | 1.41 | 0.51 | 2.01 | 1.31 | 0.75 | 57.63 | 18.97 | 98 | 0.72 |
| | 0.72 | 0.82 | 0.5 | 0.68 | 0.16 | 24.07 | 19.58 | 99 | 0.73 |
| | 1.86 | 0.5 | 2.36 | 1.57 | 0.96 | 61.18 | 19.73 | 100 | 0.74 |
| | 2.97 | 2.34 | 3.89 | 3.07 | 0.78 | 25.42 | 20.61 | 101 | 0.74 |
| | 1.68 | 1.76 | | 1.72 | 0.06 | 3.29 | 21.76 | 102 | 0.75 |
| | 0.812 | 0.694 | 0.645 | 0.65 | 0.04 | 8.34 | 22.98 | 103 | 0.76 |
| | 0.92 | 1.35 | | 1.14 | 0.30 | 26.79 | 24.07 | 104 | 0.76 |
| | 0.95 | 0.544 | | 0.75 | 0.29 | 38.43 | 24.12 | 105 | 0.77 |
| | 0.51 | 1.22 | | 0.87 | 0.50 | 58.04 | 24.28 | 106 | 0.78 |
| | 0.5 | 0.8 | | 0.65 | 0.21 | 32.64 | 24.74 | 107 | 0.79 |
| | 0.899 | 0.963 | | 0.93 | 0.05 | 4.86 | 24.86 | 108 | 0.79 |
| | 0.958 | 1 | | 0.98 | 0.03 | 3.03 | 25.42 | 109 | 0.80 |
| | 0.712 | 0.5 | | 0.61 | 0.15 | 24.74 | 25.71 | 110 | 0.81 |
| | 0.62 | 0.821 | | 0.72 | 0.14 | 19.73 | 26.30 | 111 | 0.82 |
| Molinate | ug/m3 | | 1992 p8&Tab 1 appendix | | | | 26.79 | 112 | 0.82 |
| | 0.49 | 0.51 | | 0.50 | 0.01 | 2.83 | 27.52 | 113 | 0.83 |
| | 1.1 | 1.23 | | 1.17 | 0.09 | 7.89 | 28.28 | 114 | 0.84 |
| Naled | ug/m3 | | 1991 pA-1,A-2 | | | | 28.28 | 115 | 0.85 |
| | 0.059 | 0.055 | | 0.06 | 0.00 | 4.96 | 28.28 | 116 | 0.85 |
| | 0.082 | 0.043 | | 0.06 | 0.03 | 44.12 | 30.28 | 117 | 0.86 |
| | 0.052 | 0.067 | | 0.06 | 0.01 | 17.83 | 30.55 | 118 | 0.87 |
| | 0.054 | 0.051 | | 0.05 | 0.00 | 4.04 | 30.90 | 119 | 0.88 |
| Dichlorvos | ug/m3 | | 1991 pA-1,A-2 | | | | 32.24 | 120 | 0.88 |
| | 0.024 | 0.024 | | 0.02 | 0.00 | 0.00 | 32.64 | 121 | 0.89 |
| | 0.052 | 0.049 | | 0.05 | 0.00 | 4.20 | 32.81 | 122 | 0.90 |
| | 0.023 | 0.025 | | 0.02 | 0.00 | 5.89 | 34.56 | 123 | 0.90 |
| | 0.049 | 0.029 | | 0.04 | 0.01 | 36.26 | 38.26 | 124 | 0.91 |
| | 0.059 | 0.059 | | 0.06 | 0.00 | 0.00 | 38.43 | 125 | 0.92 |
| Sodium arsenite | ng/m3 as II | | 1987 p8,9 | | | | 38.57 | 126 | 0.93 |
| | 8 | 7 | | 7.50 | 0.71 | 9.43 | 38.57 | 127 | 0.93 |
| | 76 | 71 | | 73.50 | 3.54 | 4.81 | 40.07 | 128 | 0.94 |
| | 3 | 3 | | 3.00 | 0.00 | 0.00 | 40.31 | 129 | 0.95 |
| | 2 | 2 | | 2.00 | 0.00 | 0.00 | 44.12 | 130 | 0.96 |
| | 14 | 8 | | 11.00 | 4.24 | 38.57 | 56.57 | 131 | 0.96 |
| | 2 | 2 | | 2.00 | 0.00 | 0.00 | 57.63 | 132 | 0.97 |
| Telone | ug/m3 | | 1990 p.6,7 | eeb | | | 58.04 | 133 | 0.98 |
| | 13.8 | 13.3 | | 13.55 | 0.35 | 2.81 | 61.18 | 134 | 0.99 |
| | 145.1 | 176.3 | | 160.70 | 22.06 | 13.73 | 69.57 | 135 | 0.99 |
| | 6.5 | 6.6 | | 6.55 | 0.07 | 1.08 | 78.54 | 136 | 1.00 |
| | 46.9 | 57.7 | | 52.30 | 7.64 | 14.60 | | | |
| | 8.2 | 9.7 | | 8.95 | 1.06 | 11.85 | | | |
| | 2.8 | 2.9 | | 2.85 | 0.07 | 2.48 | | | |
| | 7.3 | 7.2 | | 7.25 | 0.07 | 0.98 | | | |
| | 16.2 | 17.6 | | 16.90 | 0.99 | 5.86 | | | |
| | 1.3 | 1.4 | | 1.35 | 0.07 | 5.24 | | | |
| | 0.1 | 0.1 | | 0.10 | 0.00 | 0.00 | | | |
| | 0.2 | 0.2 | | 0.20 | 0.00 | 0.00 | | | |
| | 0.2 | 0.2 | | 0.20 | 0.00 | 0.00 | | | |
| | 0.3 | 0.3 | | 0.30 | 0.00 | 0.00 | | | |
| | 0.2 | 0.3 | | 0.25 | 0.07 | 28.28 | | | |
| | 0.2 | 0.2 | | 0.20 | 0.00 | 0.00 | | | |
| | | | | **Average CV%** | | 14.25 | | | |

Operationally, it would be difficult to devise a monitoring strategy which would overcome the variability in order to detect consistent differences at the level of 30 percent. This is the basis for describing a 30 percent difference as modest. Several caveats to the preceding statement must be mentioned. More recent 1807 studies have not been included in this analysis due to time constraints. These studies may reflect newer methods and protocols which could impact the coefficient of variation. Increased sample size can compensate for increased variability. The 30 percent difference was based on a month long average of simulated values. None of the individual measurements used in this memorandum is longer than about 1 day. A 30 percent difference over one month must be viewed as more significant than a 30 percent difference over one day. For the 1807 data used in this analysis, however, there is no obvious trend of the longer measurements (ambient) having lower coefficient of variation than the shorter measurements (application). The shorter application monitoring time periods give about the results when compared to the longer ambient monitoring time periods. This analysis is based on different chemicals which were analyzed by different groups at different times. A particular chemical and laboratory may produce lower coefficient of variation. I have not undertaken analysis of the data to determine whether or not they are normally distributed. The fact that the means and medians are somewhat different suggests some skew in the data, which would indicate non-normality. However, I am relying on the robustness of the ANOVA procedure to reasonably gauge the significance of each factor. The ANOVA results are certainly consistent with common sense in this case. Finally, not using data labeled as 'ND' (not-detected) has probably reduced the coefficient of variation. However, a more comprehensive treatment of ND data is beyond the scope of this effort.

Please contact me if you have any questions.

Table 3. Summary of coefficient of variation statistics.

| | Application Monitoring | | Ambient Monitoring | |
|---|---|---|---|---|
| | Collocated | Simultaneous | Collocated | Simultaneous |
| Mean | 15% | 85% | 14% | 75% |
| Median | 7% | 78% | 9% | 67% |

The differences between application and ambient monitoring, in terms of the means and medians, are negligible. Analysis of variance using general linear models (GLM) command in Minitab Release 9.2 (1993) found only collocation/simultaneous had statistically significant effect ($p<0.01$) on the coefficient of variation (Table 4).

Table 4. Analysis of Variance for coefficient of variation.

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| App-Amb | 1 | 12251 | 1795 | 1795 | 1.76 | 0.186 |
| Col-Sim | 1 | 267686 | 258004 | 258004 | 252.79 | 0.000 |
| A-A*C-S | 1 | 1542 | 1542 | 1542 | 1.51 | 0.220 |
| Error | 287 | 292919 | 292919 | 1021 | | |
| Total | 290 | 574397 | | | | |

While the ANOVA may be simply restating the obvious, it is now possible to address the original question, is a 30 percent concentration difference "modest"? Based on the variability of simultaneous measurements, a 30 percent difference fades well below the level of noise. In other words, spatial variability in concentration measurements would overwhelm differences of 30 percent. For sampling variability as measured by the collocated analyses, the picture is brighter, but still contains a healthy variance. When 15 percent is used as a standard deviation (i.e. 100 percent is the mean) and normality is assumed, then a two-sided 95 percent confidence interval stretches from 71 percent to 129 percent, an interval with a length of 58 percent, almost double the 30 percent difference.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.31 | 1.1 | 1.9 | | | 1.10 | 0.80 | 72.05 | 85.02 | 36 | 0.60 |
| | 2.2 | 5.8 | 10 | 12 | | 7.50 | 4.38 | 58.36 | 86.14 | 37 | 0.62 |
| | 0.029 | 6 | 17 | 18 | | 10.26 | 8.72 | 85.02 | 90.60 | 38 | 0.63 |
| | 2.1 | 7.8 | 11 | | | 6.97 | 4.51 | 64.71 | 96.70 | 39 | 0.65 |
| | 0.92 | 5.7 | 10 | | | 5.54 | 4.54 | 81.99 | 98.73 | 40 | 0.67 |
| | 0.34 | 0.43 | 3 | | | 1.26 | 1.51 | 120.19 | 100.47 | 41 | 0.68 |
| | 0.07 | 1.2 | 4.5 | 8.4 | | 3.54 | 3.74 | 105.69 | 102.98 | 42 | 0.70 |
| Molinate | ug/m3 | | 1992 Table II p6 | | | | | | 105.69 | 43 | 0.72 |
| | 0.4 | 0.4 | | | | 0.40 | 0.00 | 0.00 | 109.98 | 44 | 0.73 |
| | 0.16 | 0.9 | | | | 0.53 | 0.52 | 98.73 | 110.05 | 45 | 0.75 |
| | 0.48 | 1.17 | | | | 0.83 | 0.49 | 59.14 | 110.89 | 46 | 0.77 |
| | 0.5 | 0.51 | | | | 0.51 | 0.01 | 1.40 | 118.88 | 47 | 0.78 |
| | 0.26 | 0.64 | | | | 0.45 | 0.27 | 59.71 | 120.19 | 48 | 0.80 |
| Sodium arsenite | ng/m3 | | 1987 Table 2 p8 | | | | | | 127.70 | 49 | 0.82 |
| | 3 | 16 | 8 | 70 | | 24.25 | 30.97 | 127.70 | 132.24 | 50 | 0.83 |
| | 6 | 5 | 3 | 74 | 6 | 18.80 | 30.88 | 164.27 | 137.99 | 51 | 0.85 |
| | 3 | 2 | 3 | 3 | 3 | 2.80 | 0.45 | 15.97 | 148.25 | 52 | 0.87 |
| | 54 | 12 | 11 | 5 | | 20.50 | 22.55 | 109.98 | 149.68 | 53 | 0.88 |
| | 2 | 2 | 2 | | | 2.00 | 0.00 | 0.00 | 150.18 | 54 | 0.90 |
| Telone | ug/m3 | | 1990 eeb Table II, p6 | | | | | | 164.27 | 55 | 0.92 |
| | 3.2 | 6.4 | 2 | 7.5 | 13.5 | 6.52 | 4.50 | 69.08 | 165.26 | 56 | 0.93 |
| | 1.2 | 2.8 | 0.3 | 34.8 | 160.7 | 39.96 | 69.03 | 172.75 | 167.42 | 57 | 0.95 |
| | 0.8 | 3.1 | 2.3 | 67.2 | 6.6 | 16.00 | 28.70 | 179.38 | 172.75 | 58 | 0.97 |
| | 0.6 | 5.3 | 2.9 | 2.9 | 52.3 | 12.80 | 22.14 | 173.00 | 173.00 | 59 | 0.98 |
| | 0.3 | 8.95 | 33.3 | 14.4 | 72.4 | 25.87 | 28.69 | 110.89 | 179.38 | 60 | 1.00 |
| | 0.2 | 2.8 | 2.2 | 2.2 | 6 | 2.68 | 2.10 | 78.38 | | | |
| | 0.5 | 7.25 | 2.6 | 53.7 | 10.3 | 14.87 | 22.04 | 148.25 | | | |
| | 0.4 | 16.9 | 4.9 | 138.6 | 15.3 | 35.22 | 58.21 | 165.26 | | | |
| | 0.2 | 1.2 | 1.35 | 14.6 | 2.6 | 3.99 | 5.99 | 150.18 | | | |
| | 0.3 | 0.1 | 5.8 | 1.5 | | 1.93 | 2.66 | 137.99 | | | |
| | 0.2 | 0.2 | 8.5 | 0.8 | | 2.43 | 4.06 | 167.42 | | | |
| | 0.2 | 3.3 | 0.7 | | | 1.40 | 1.66 | 118.88 | | | |
| | 0.2 | 0.25 | | | | 0.23 | 0.04 | 15.71 | | | |
| | 0.2 | 0.1 | | | | 0.15 | 0.07 | 47.14 | | | |
| | | | | | | **Average CV %** | | **74.68** | | | |

**Table 2B. Ambient 1807 monitoring -- simultaneous measurements**

| | | | | | | Mean | SD | CV % | Sorted | | %tile |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Azinphos-methyl | ppt | | 1987 p.22 Table 7 | | | | | | | | |
| 2.2 | 1.6 | 2.4 | 3 | 1.2 | | 2.08 | 0.70 | 33.72 | 0.00 | 1 | 0.02 |
| Chloropicrin | ug/m3 | | 1986 p.24 Table 9 | | | | | | 0.00 | 2 | 0.03 |
| 0.151 | 0.35 | 0.172 | | | | 0.22 | 0.11 | 48.74 | 1.40 | 3 | 0.05 |
| Methidathion | ug/m3 | | 1991 Table | | | | | | 2.90 | 4 | 0.07 |
| 0.027 | 0.032 | 0.019 | 0.014 | | | 0.02 | 0.01 | 34.96 | 5.16 | 5 | 0.08 |
| 0.0235 | 0.018 | | | | | 0.02 | 0.00 | 18.74 | 7.16 | 6 | 0.10 |
| 0.011 | 0.031 | 0.07 | 0.014 | | | 0.03 | 0.03 | 86.14 | 13.22 | 7 | 0.12 |
| Methidaoxon | ug/m3 | | 1991 Table | | | | | | 15.71 | 8 | 0.13 |
| 0.042 | 0.035 | 0.043 | 0.075 | | | 0.05 | 0.02 | 36.63 | 15.97 | 9 | 0.15 |
| 0.0595 | 0.051 | 0.037 | 0.055 | | | 0.05 | 0.01 | 19.21 | 18.32 | 10 | 0.17 |
| 0.07 | 0.11 | 0.12 | 0.062 | | | 0.09 | 0.03 | 31.79 | 18.74 | 11 | 0.18 |
| 0.067 | 0.063 | 0.046 | 0.049 | | | 0.06 | 0.01 | 18.32 | 19.21 | 12 | 0.20 |
| 0.084 | 0.061 | 0.039 | 0.078 | | | 0.07 | 0.02 | 30.80 | 21.96 | 13 | 0.22 |
| 0.057 | 0.1035 | | | | | 0.08 | 0.03 | 40.97 | 30.80 | 14 | 0.23 |
| 0.033 | 0.07 | 0.057 | | | | 0.05 | 0.02 | 35.19 | 31.79 | 15 | 0.25 |
| 0.092 | 0.11 | 0.12 | | | | 0.11 | 0.01 | 13.22 | 32.20 | 16 | 0.27 |
| Methyl parathion | ng/m3 | | 1986 Table 11 p.42 | | | | | | 32.52 | 17 | 0.28 |
| 0.53 | 0.72 | 6.65 | 1.03 | | | 2.23 | 2.95 | 132.24 | 33.72 | 18 | 0.30 |
| 1.05 | 0.5 | 25.67 | 4.69 | | | 7.98 | 11.94 | 149.68 | 34.96 | 19 | 0.32 |
| 0.54 | 0.5 | 21.53 | 21.75 | | | 11.08 | 12.19 | 110.05 | 35.19 | 20 | 0.33 |
| 0.37 | 13.8 | 5.56 | | | | 6.58 | 6.77 | 102.98 | 36.63 | 21 | 0.35 |
| 14.9 | 5.31 | | | | | 10.11 | 6.78 | 67.11 | 40.97 | 22 | 0.37 |
| 5.01 | 5.22 | | | | | 5.12 | 0.15 | 2.90 | 47.14 | 23 | 0.38 |
| 1.1 | 13.97 | 4.74 | | | | 6.60 | 6.63 | 100.47 | 48.23 | 24 | 0.40 |
| 7.72 | 1.45 | | | | | 4.59 | 4.43 | 96.70 | 48.74 | 25 | 0.42 |
| 2.13 | 1.34 | | | | | 1.74 | 0.56 | 32.20 | 58.36 | 26 | 0.43 |
| 5.73 | 1.82 | | | | | 3.78 | 2.76 | 73.24 | 59.14 | 27 | 0.45 |
| 0.71 | 0.66 | | | | | 0.69 | 0.04 | 5.16 | 59.71 | 28 | 0.47 |
| Methyl paraoxon | ng/m3 | | 1986 Table 15 p47 | | | | | | 64.71 | 29 | 0.48 |
| 2.32 | 1.14 | | | | | 1.73 | 0.83 | 48.23 | 67.11 | 30 | 0.50 |
| 0.83 | 0.75 | | | | | 0.79 | 0.06 | 7.16 | 69.08 | 31 | 0.52 |
| 0.68 | 0.93 | | | | | 0.81 | 0.18 | 21.96 | 72.05 | 32 | 0.53 |
| 1.15 | 0.72 | | | | | 0.94 | 0.30 | 32.52 | 73.24 | 33 | 0.55 |
| MITC | ug/m3 | | 1993 Table III p7 | | | | | | 78.38 | 34 | 0.57 |
| 0.4 | 0.45 | 0.98 | 2.5 | | | 1.08 | 0.98 | 90.60 | 81.99 | 35 | 0.58 |

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