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DISPERSION EXPERIMENTS USING SHORT-TERM RELEASES OF AN ATMOSPHERIC TRACER

by

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1. INTRODUCTION

The Mesoscale Atmospheric Transport Studies (MATS) experiments were undertaken to provide a data base for determining the accuracy of mesoscale atmospheric dispersion model predictions for short term releases. The MATS experiments described below were conducted during 1983. A new series began in 1985 and will continue into 1986.

The MATS experiments provide information on crosswind and downwind spread of material. The horizontal spread was obtained with a crosswind system of samplers while downwind spread was measured by collecting a sequence of continuous, relatively-short-time-samples as the plume moved downwind. It was assumed that the structure of the plume changed slowly as it moved across the sampling arc.

Our interest is in transport and dispersion on the meso-scale and a 30km distance for the arc of samplers corresponds geographically with an approximately circular series of highways where vehicles could deploy samplers alongside the roads (see Figure 1).

The MATS experiments were conducted on randomly chosen workdays. Since they were performed during working hours, the stability regimes are biased toward neutral and unstable. A second series of MATS experiments is planned during 1985 with a new continuous sampler that can be used at night from a moving vehicle. These experiments will provide data on a stable regime.

2. METHOD AND PROCEDURE

2.1 Stack Parameters

The MATS experimental series was initiated on January 18, 1983. All experiments began with a 15 minute release of sulphur-hexafluoride from a 62m stack in H-Area to form a cloud. The vertical exhaust velocity at the top of the 3.33 m diameter stack was 6.66 m/s. The effluent was atmospheric air used in the ventilation system of a nearby building. This ventilation air was used throughout the building and its temperature upon release was reasonably close to the ambient temperature (except in the colder months). There were no significant structures (greater than 0.4 stack height) within ten stack heights horizontally of the release point so building wake effects were not expected.

2.2 Sampling Method

During each experiment, two sampling teams were dispatched to the intersection of the forecast plume centerline and the 30-km arc shown on Figure 1. Each sampling team consisted of two technicians in a van, carrying maps and half of the complement of samplers. After the sampling teams arrived at the site, a revised forecast of the intersection point was given based on the latest average of 15-minute wind and turbulence information. The two sampling teams then moved to the new sampling location and fastened the samplers to fence-lines, telephone poles, trees, etc. at a spacing based on Pasquill-Gifford sigma-y's but modified to take into account wind-shear effects. The modification was subjective and based on previous experience from similar releases.

2.3 Samplers

The sampling in the first 10 MATS experiments was done with evacuated samplers. These samplers are actuated electronically after setting a digital binary switch. Both the actuation time and the time interval to switch sequentially to the next canister were forecast based on expected plume arrival time and downwind spread. Switching from one canister to the next was done by an electro-mechanical pressure manifold.

The sampling time refers to time taken to fill one of seven evacuated aluminum canisters. The sampling time was chosen to obtain the best resolution of the plume's downwind dispersion. Sampling times were as short as 7 minutes and as long as 20 minutes, but 15 minutes was a typical period.

The first ten MATS experiments used evacuation type samplers. The next four MATS experiments included a combination of the evacuated samplers and new samplers purchased from Demaray Scientific Instruments. The Demaray instruments sampled sequentially as did the evacuated samplers but, instead of a large evacuated canister, a 60 mL syringe was filled while being driven with a pulsed DC motor. The syringe was sealed at the end of the sampling period by driving it into a septum at the base of the sampler. Both activation and sampling time were programmable for both types of samplers. The Demaray samplers had 10 syringes to fill during the experiment. Thus better time resolution was obtained with the Demaray samplers than with the evacuation instruments.

2.4 Sampler Deployment

The samplers were deployed at regular intervals along the roads shown in Figure 1. The numbered landmarks indicated in Figure 1 were used to help the sampling teams navigate. Vehicle odometers were used to measure distance along the roadway from the center point. These distances were later converted into UTM

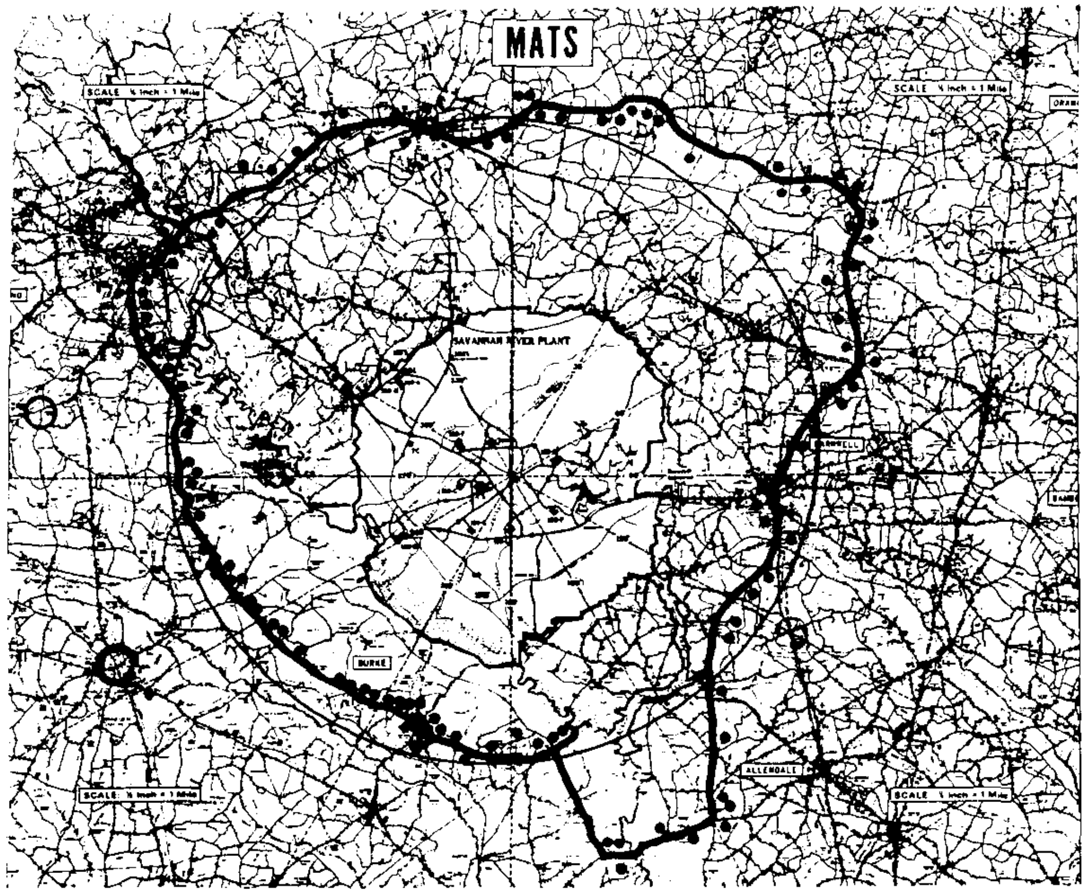

Figure 1. Map of the Savannah River Plant and the surrounding communities. The heavy line indicates the series of public roads where air samplers were deployed for the MATS experiments. The circled numbers designate the positions of landmarks such as churches and bridges. The light circle is drawn with a radius of 30km from H-Area.

coordinates by a map digitizer over-laying the map in Figure 1. The accuracy of the arc center of the sampler positions determined in this way was estimated to be about ± 200m. The relative accuracy of sampler spacing for a given experiment was better, perhaps ± 100m, because it was based on vehicle odometer readings.

Time checks with the computer were made prior to each experiment so the timing error was less than one minute. Since completing the first 14 MATS experiments, a LORAN system has been added to determine sampler positions to ± 100m.

2.5 Gas Chromatography Analysis

After the samplers were retrieved from the roadside and transported back to the laboratory, a gas-chromatography analysis was performed to determine the concentration of SF_6 in each canister or syringe. The pressure in each canister was generally slightly lower than ambient atmospheric pressure when they arrived at the laboratory. To facilitate the removal of the contents of the canisters, pure nitrogen was allowed to flow into the canisters through a manifold from a pressurized cylinder. Each canister was slightly overpressured with nitrogen. Then, several milliliters of the contents of the canister were pumped into one of three electron capture gas chromatographs (S-Cubed). The digital result from the chromatograph was recorded and translated into an SF_6 concentration with calibration curves. The calibration was checked three to four times for each chromatograph during the analysis by comparison with a known dilute concentration of SF_6. For all MATS experiments, the gas analysis was completed in the work shift following return of the samplers; i.e., 4:15 pm to 11:45 pm LST. This practice minimized the possiblility of mislabeled samples, incorrect times, and other procedural errors.

3. ANALYSIS

The speed and direction of the SF_6 cloud's movement are of practical and theoretical interest. During the MATS experiments, wind data were collected from a 60m tower located within 2 1/2 km of the release stack (H area). Additional wind data were obtained from six 60m towers at SRP, and from 6 levels on the 300m WJBF TV tower (22 km from the release stack). The speed and direction of the cloud movement inferred from

TABLE 1.

DIRECTION AND SPEED PERFORMANCE OF VARIOUS WIND SENSORS FOR THE MATS EXPERIMENTS

Sensor	Direction Statistics (degrees)			Speed Statistics (m/s)		
	Bias	Std. Dev.	RMS	Bias	Std. Dev.	RMS
304m (WJBF)	-7.0	8.2	10.6	-0.84	2.3	2.3
243m (WJBF)	-6.1	12.4	13.4	-0.76	2.0	2.1
182m (WJBF)	-2.5	9.5	9.5	-0.24	1.6	1.5
137m (WJBF)	-3.2	8.7	9.0	-0.21	1.3	1.3
60m (H area)	6.0	10.4	11.7	1.0	1.1	1.4
60m (SA)	4.2	8.3	9.1	1.1	1.1	1.5

these instruments are compared with the observed cloud movement in Table 1. This table lists the bias, standard deviation, and root mean square error (AMS definitions: Fox, 1981) of the bivane predictions at 4 levels on the TV tower, on the H area tower, and for an average of 6 SRP area towers (SA).

Inspection of the table shows that the 182m and 137m levels of the WJBF tower were the least biased and also the most accurate (lowest RMS error) indicators of cloud direction. These same 2 levels were also the least biased and most accurate measures of cloud speed. The relatively good performance of the 137m and 182m wind instruments was expected since the SF_6 clouds were non-buoyant and therefore should not rise significantly above their 60m release points, and because these two levels should be good indicators of mean wind speed in the boundary layer.

The values of sigma-x and sigma-y obtained from the MATS experiments were compared with theoretical predicitions of Draxler (1976) and Pasquill (1977). Sigma-x and sigma-y were obtained from the second moment of the concentration distribution using the formuala:

$$(\text{sigma-y})^2 = \Sigma(y_i - y_{cm})^2 \, c_i / \Sigma c_i$$

where c_i equals the SF_6 concentration and y_i and y_{cm} are the positions of the i'th sample and the cloud center of mass locations respectively. Figure 2 shows a scatter plot of sigma-y values obtained from Draxler's (1976) model compared with the MATS observations. The correlation coefficient is 0.80. Figure 3 shows a scatter plot identical to that of Figure 2 but for Pasquill's (1976) model and the MATS observations. The correlation coeficient for this case was 0.91. Thus, Pasquill's model predicted the observed sigma-y's with greater skill than Draxler's. The probability that the two correlation coefficients were statistically different was calculated and found to be 81%.

Sigma-x was determined in a manner similar to sigma-y after samples gathered sequentially in time were converted to distance with the center of mass speed. Figure 4 shows a scatter plot of measured sigma-x values and the predicted values of sigma-y from Pasquill (1976). No correlation between the predicted sigma-y and observed sigma-x values is evident.

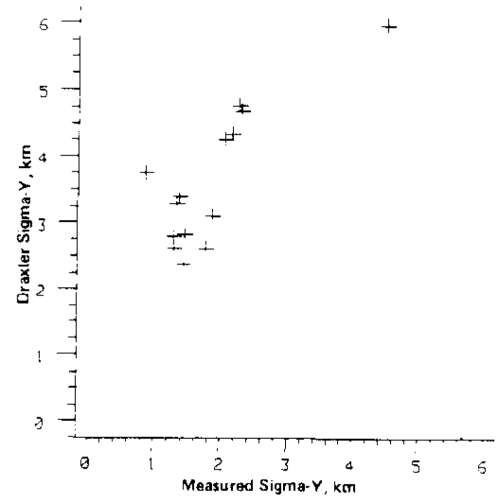

Figure 2. Scatter plot of sigma-y values calculated from the Draxler (1976) model and sigma-y values measured in the 14 MATS experiments.

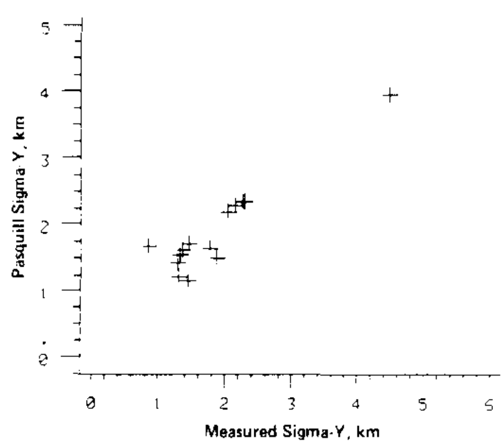

Figure 3. Scatter plot of sigma-y values calculated from the Pasquill (1976) model and sigma-y values measured in the 14 MATS experiments.

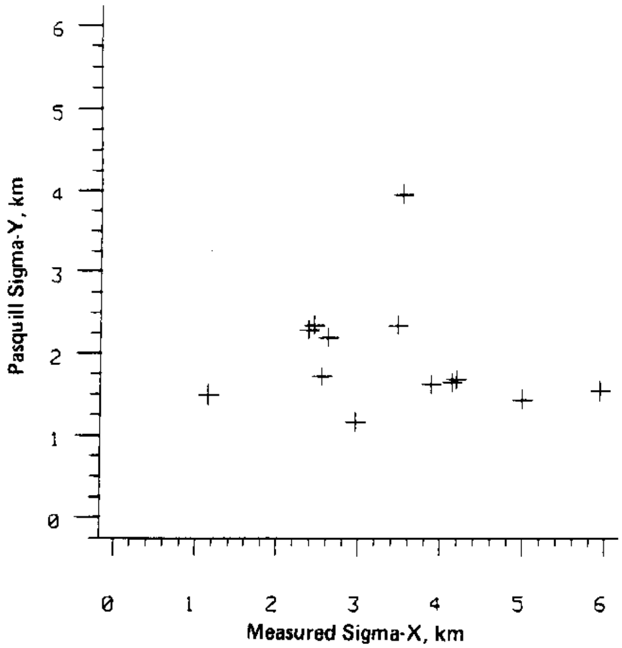

Figure 4. Scatter plot of sigma-y values calculated from the Pasquill (1976) model and sigma-x values measured in the 14 MATS experiments.

4. CONCLUSIONS

This paper has described the MATS experiments and compared observed dispersion parameters with theory. The movement of the sulfur hexafluoride cloud has been compared with that calculated from wind sensors placed at several different elevations. The observed sigma-y values were also compared with theory and found to agree well with Pasquill's (1976) method.

The MATS experiments are an important part of the Laboratory's dispersion research and will continue to provide valuable information on important dispersion parameters for models.

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5. REFERENCES

Draxler, R., 1976: Determination of atmospheric diffusion parameters. Atmospheric Environment, 10, 95-105.

Fox, D. G., 1981: Judging air quality model performance. Bullentin of the American Meteorological Society, Vol. 62, No. 5, May 1981, 599-609.

Gifford, F. A., 1976: Turbulent diffusion-typing schemes: a review, Nuclear Safety, 17, no. 1, 68-86.

Pasquill, F., 1974: Atmospheric Diffusion, Second Edition, Halsted Press: a division of John Wiley and Sons, New York, NY, 429pp.

Pasquill, F., 1976: Atmospheric dispersion parameters in Gaussian plume modeling part II. EPA-600/4-76-030b, 43pp.