LA-UR -80-791

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SUBMITTED TO: 2nd Joint Conference on Applications of Air Pollution Meteorology, American Meteorological Society, New Orleans, LA, March 24-27, 1980

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CONTRACT W-7405-ENG. 36

EFFECTIVE TRANSPORT VELOCITY AND PLUME ELONGATION IN NOCTURNAL VALLEY WIND FIELDS

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1. INTRODUCTION

The problem of turbulent diffusion in simple shear flows has been studied by several authors including Tyldesley and Wallington (1965) and Gee and Davies (1963). As a plume of pollutant or tracer material expands vertically it encounters air moving at a different bulk velocity and also may encounter different scales or intensities of turbulence. The domain of valley drainage winds is an extension of the classical case in which the mean wind and turbulence fields are generally more complicated with a low-level maximum and vary with time and position in the valley. The confinement of the valley walls is an additional complicating factor to plume behavior.

In this paper we report on the results of several tracer experiments conducted in three valleys of differing structure during nighttime drainage wind conditions. These experiments were designed to document the effective transport velocity between points along the drainage wind path and the plume's elongation during the transit time.

The sites investigated in these studies are:

- Los Alamos Canyon (LAC), NM; a narrow steep walled mountain canyon,
- Anderson Creek Valley (ACV), [illegible] a relatively small air shed, and
- Grants Basin (GB), NM two converging air sheds.

The general characteristics of each site are given in Table 1. Space does not permit detailed maps or descriptions of each site and the items in Table 1 are given for general comparisons only. Additional topographical information for individual sites will be given when necessary in the discussion of the results below.

2. EXPERIMENTAL METHOD

Tracer material was released near ground level in the center of each valley in a well established nocturnal drainage wind field. The resulting tracer plume was sampled sequentially at 10-15 min. intervals at downwind locations. Tracers used were fluorescent particles (FP), SF_6, and a heavy methane ($^{13}CH_4$). The sequential sampling was accomplished with rotored samplers for the FP tracers and bag samplers for the gaseous tracers. Three experiments were conducted in LAC, four in ACV, and one in GB. The dates of each experiment, the tracer used, and its release data are given in Table 2. All tracer releases were made in a well established nocturnal drainage wind.

The arrival time of the tracer material at the sampling sites is a measure of the effective transport velocity to that site and is compared in each case to that estimated from surface (1.5 m above ground) wind measurements during the experiment. The length of the plume determined from the sequential samples is compared to the duration of the release to investigate lateral plume deformation. To provide an objective analysis the plume arrival time and plume width are in all cases calculated at 10% of the peak value of the plume.

3. RESULTS

We will now discuss our observations of effective transport velocity and plume elongation for each individual site.

3.1 Los Alamos Canyon (LAC)

Three tracer releases were made in LAC from the same location on three different nights. (See Table 1). Sequential bag samples were taken at 10 to 15 min. intervals at a location [illegible] down canyon from the release point. Two of these experiments used [illegible], as the tracer and the third employed $^{13}CH_4$. Details of the terrain and some characteristics of the nocturnal wind flow in LAC are discussed by Clements and Barr [illegible] and Archuleta et al. [illegible]. Figure 1 shows the concentration of the tracer at the sampling site as a function of time after release for each of the three experiments. Each release lasted [illegible] min., as denoted by the length of the horizontal bar in the upper left hand corner of the figure. The effective transport velocity (V eff), mean measured surface wind [illegible], and plume elongation for these experiments are presented in Table 3. The plume elongation is expressed as a factor of the release duration. The mean measured winds were recorded at 1.5 meters above the canyon floor at a location about half way between the release and sampling sites. The values for V recorded in Table 3 are the mean wind speeds from the time of release to the plume arrival at the sampler. The agreement between [illegible] and V eff is very good. Another wind instrument further down the canyon in heavier canopy measured mean wind speeds at about a half to one third the speeds at the more representative site. Elongation factors for these three experiments were from [illegible].

3.2 Anderson Creek Valley (ACV)

Four FP releases were made near the top of Anderson creek in ACV on four separate nights in July 1979 (see Tables 1 and 2) as part of a complex terrain study sponsored by the U. S. Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) program (Dickerson and Gudiksen, 1980a). Sequential samples were taken at 10 to 15 minute intervals at locations 2.5, 4.9, and 6.4 km downvalley with rotorod samplers. The characteristics of ACV given in Table 1 refer mostly to the first 3 km from the release point. After that distance Anderson Creek opens out into a broader basin where it is joined by several other small drainage features which then together make up the drainage flow in ACV to the sampling stations at 4.9 and 6.4 km. Hence, the upper portion of ACV is a fairly well confined drainage region while the lower portion is much more complicated. For details of the topography see Dickerson and Gudiksen (1980a,b).

The results of our four tracer experiments in the nocturnal drainage flow of ACV are shown in Figs. 2-5. The duration of the release for each case is shown by a horizontal line in the upper left-hand corner of each figure. Experiments 1-3 show similar behavior of the plume at each sampling location. Sampling was stopped before complete plume passage in the first experiment (Fig. 2) and, hence, some data was not obtained. In the last ACV experiment (Fig. 5) the plume behaved pretty well as it past the 2.5 km sampler, but light and variable winds further down in the valley caused very erratic behavior at the 4.9 and 6.4 km samplers.

A summary of the effective transport and velocity, mean measured surface wind (V) and the elongation factor at each site for each of the 4 experiments is given in Table 4. The measured surface wind reported in this table was computed from wind data collected 1.5 m above ground near the 2.5 and 4.9 km sampling stations. Each value represents an average of the wind speeds at each station weighted by the time the plume was present in that field as determined by its arrival time at each sampler. Several trends in the data of Table 4 should be pointed out.

First V-eff from the release point to both the closest (2.5 km) and farthest (6.4 km) samplers are fairly uniform averaging 1.7 ± 0.3 m/s for the eight values. The measured mean speeds for these two stations are all (except ACV-3) slightly higher than V eff with a mean difference of 0.5 m/s. This could easily be accounted for in the location of the instruments used to make the computations. Basically then for the 2.5 and 6.4 km samplers the mean surface wind in the valley center slightly over estimates the plume arrival time at these two stations.

A mystery arises in the V eff data for the middle sampler (4.9 km) in the first three ACV experiments. Each of these experiments give 2.0 m/s for V eff to the 4.9 km sampler which is 60% higher than V-eff to the samplers on either side of it. In ACV-1 and ACV-3 the measured wind speed approach that value for that sampler. Until further analysis on additional wind data can be made this will just have to remain a curiosity and fuel for speculation.

The elongation factors determined at the 2.5 km sampler were constant for the first three experiments and only 40% higher for the last one (see Table 4). At the other samplers (4.9 and 6.4 km) the elongation factors varied considerably probably reflecting the more complicated nature of the valley in the areas they were located.

3.3 Grants Basin (GB)

Only one tracer experiment has been performed in the Grants Basin area at this writing. The Grants Basin area really consists of two air sheds which converge and empty into a much broader basin to the south. For specific terrain details see Gedayloo et al. (1979, 1980). Our experiments consisted of releasing SF_6 in the more northerly air shed (Ambrosia Lake) at a point 4.5 km from the point of convergence of the two air sheds. One sampler was located at the convergence point and another 7.3 km south of that point in the broader open basin. Hence, samplers were located at 4.5 and 11.8 km from the release point along the path of the nocturnal drainage air flow.

Figure 6 shows the passage of the plume at both stations during the period after the release. The plume appears to have maintained its general character as it passed both stations. Table 5 gives the transport characteristics at each sampling station for this experiment. Again the measured surface wind velocity and effective transport velocity agree quite well. The measured surface wind for the 4.5 km sampler was computed as in the other experiments from a wind instrument located between it and the release point. The measured wind for the 11.8 km station was derived by averaging the mean surface wind speeds from three instruments located along the plume path weighted by the time the plume was present in the representative wind field as determined by plume arrival time at the sampler. These wind stations were located near the release point, the 4.5 km sampler, and the 11.8 km sampler.

The majority of the plume elongation in this experiment seems to have occurred in the first 4.5 km as there is only a 20% increase in plume width in the next 7.3 km of travel.

4. SUMMARY AND CONCLUSIONS

Using three atmospheric tracers we have investigated the effective transport velocity and plume elongation produced by nocturnal drainage wind in three different valleys. Tracer was released in each valley in a well defined drainage wind field and sequentially sampled at downvalley locations. The effective transport velocity (V eff) was determined from the elapsed

time from the start of the release to the time when the plume concentration reached 10% of its peak value and the distance from the release site. The plume elongation factor was determined from the ratio of the width (time) of the plume at 10% of its peak value to the duration of the release. This method was chosen as an objective analysis scheme. Mean measured winds (V) were computed from surface wind instruments along the drainage flow path with values weighted by the estimated time the plume was in the wind field best represented by a measurement. The values used were from the start of release to the time of arrival at the sampler in question. V is compared to V-eff to see how reasonable an estimate of plume transport in valleys can be made from a few surface measurements in the valley.

Table 6 summarizes the mean transport characteristics for each study site. AcV and GR have been broken down by the various transport distances studied. Data from AcV-1 at 0.4 km and from AcV-4 at 4.0 and 6.4 km were not considered reliable enough to draw definitive conclusions (see Figs. 2 and 5).

In the LA series of experiments and the G experiment we found the mean surface wind V to be a fairly good indicator of V-eff. Reasonable agreement was found at A-V-b and A-V-c, while V at A-V-a was on the average 50% higher than V-effective. The AcV site is by far the more complicated terrain and, hence, these differences are not unexpected.

If we exclude A-V-b and A-V-c from the data set for reasons stated earlier, then V-eff ranges from 1.1 to 2.0 m/s for all sites (LA, AcV, and G) with a mean of 1.4 m/s. Therefore, we can say that in these three valleys of quite different but well defined structure (see Table 1) there is not a wide range of drainage flow velocities.

In the A-V series of experiments there were three cases where V-eff was greater at the 1.6 km range than at the ones on either side of it at 0.4 and 6.4 km. Further investigation of the wind fields, especially vertical shear data, will have to be done before we can attempt to understand this apparent anomaly.

The measured elongation factors ranged from a high of 5.0 at 0.4 km in A-V to a low of 2.0 km in A-V. The mean elongation factor in Table 6 show a wide variation, while the elongation factor per kilometer of travel distance varies less and is probably a more realistic value to compare. The only real inconsistency in the elongation data is in the G experiment where the plume elongated by a factor of 2.2 in the first 4.0 km and only 20% more in the next 2.0 km of travel. Plume elongation is intimately tied to the shear structure as discussed for simple cases by Sylbeckey and Wallington (1969) and Gee and Olsen (1979). We cannot expect to relate our surface measurements to the elongation effect. In fact much more is going to have to be learned about shear flows in valleys and the effect of the canopy before the lateral plume elongation problem in valleys will be well tractable. Here we have observed some elongation factors that one might expect in similar valleys under similar conditions.

The simple tracer technique used in our studies has proven to be a good one in accomplishing our stated objective of investigating effective transport velocity and plume elongation in nocturnal valley drainage winds. This type of data should be collected in any serious study of valley drainage flow as it is simple to perform and provides important information, probably more so than we have gleaned out of our data in this short paper.

5. ACKNOWLEDGMENTS

There are many individuals who helped accomplish the work presented in this paper. The fact that there are too many to list in no way detracts from our appreciation for their assistance. This work was supported by the U. S. Department of Energy, Office of Health and Environmental Research.

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[illegible]

[illegible]

[illegible]

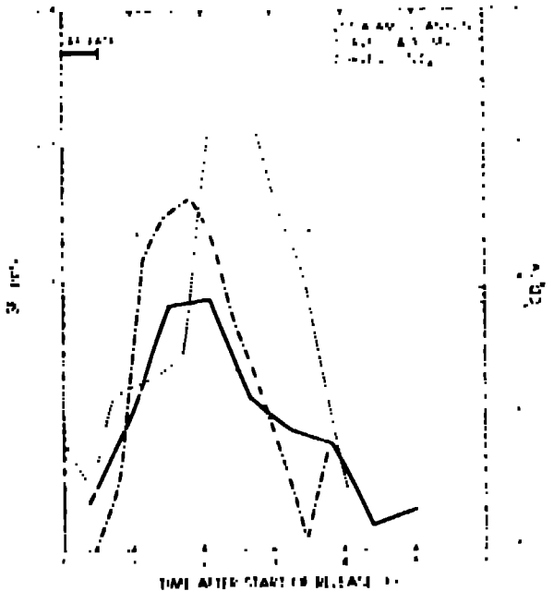
[illegible]

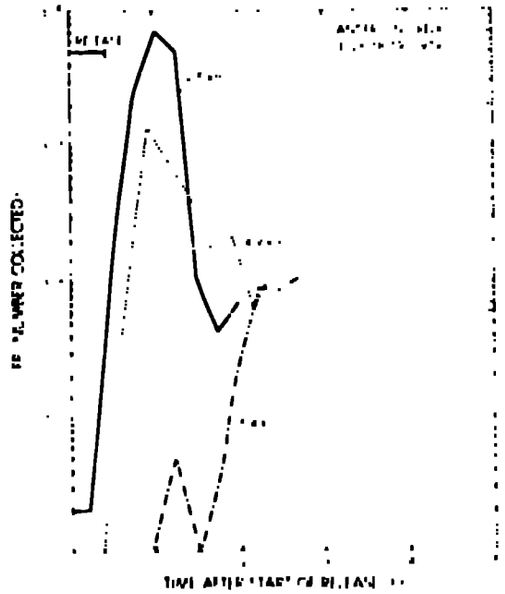
Table [illegible]

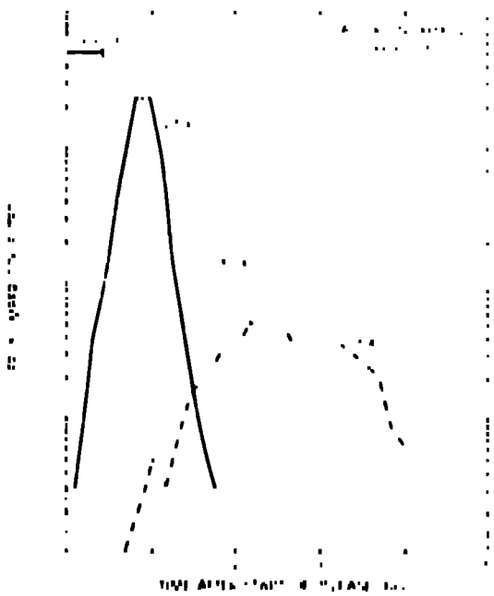
[illegible]

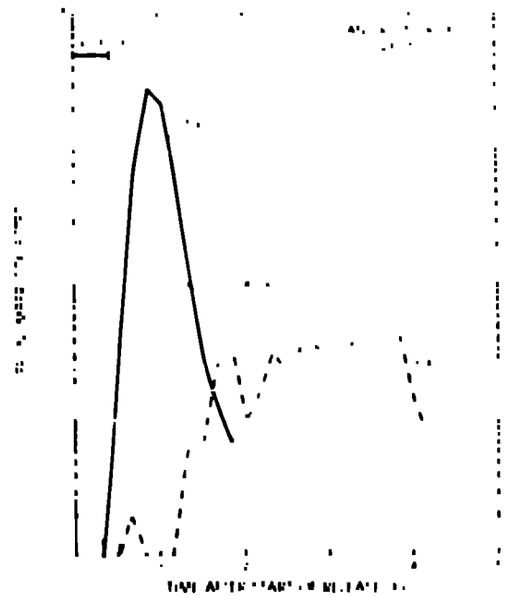
Experiment	[illegible]	[illegible]	[illegible]
IA [illegible]	1.9	2.2	[illegible]
IA [illegible]	[illegible]	1.6	[illegible]
IA [illegible]	1.[illegible]	1.0	[illegible]

[illegible]









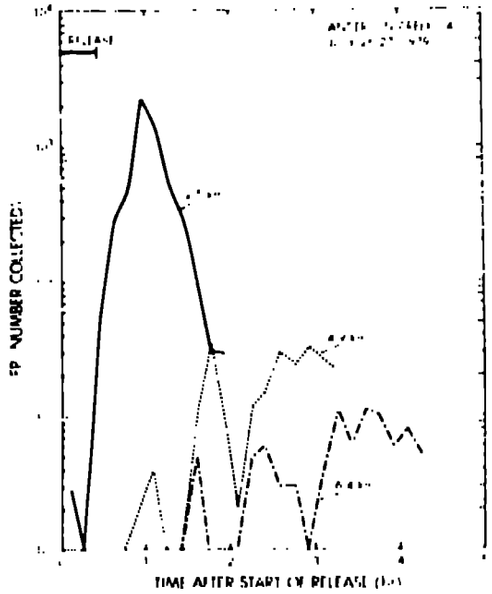


Fig. 5. Tracer plume concentration as a function of time at three downvalley locations in A.V. Curves are labeled with kilometers from the tracer release point. The release started at 23[illegible] PST and lasted 20 minutes.

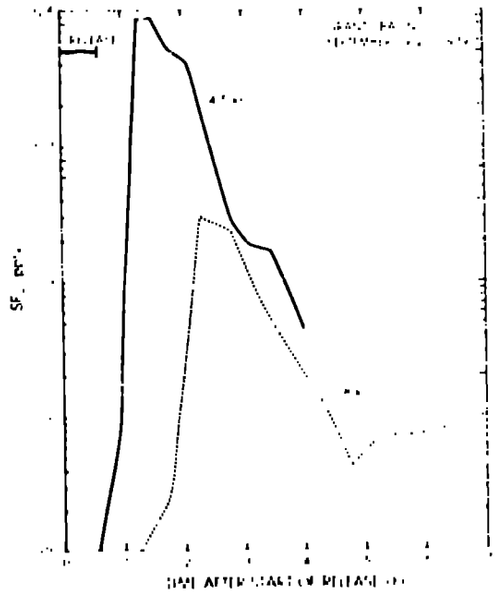


Fig. 6. Tracer plume concentration as a function of time at two locations along the drainage wind flow. Curves are labeled with kilometers from the release point. The release started at 2115 MST and lasted 30 minutes.