P1.21 Gas dispersion trials: a surface area source enclosed by a windbreak

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1 Introduction

As a simple alternative to direct measurements, it may sometimes be useful to diagnose the strength (Q) of a finite surface area source of a trace gas, from nearby measurement(s) of concentration (C) at a point P. This is sometimes called "inverse dispersion", and requires the use of a suitable dispersion model, which must be provided measurements of the atmospheric state: at a minimum, the friction velocity u_*, Obukhov length L, roughness length z_0, and mean wind direction β. The procedure could be represented symbolically as:

$$Q^{(est)} = Q^{(est)}\left(C_P | u_*, L, z_0, \beta\right) \qquad (1)$$

A particularly flexible instance of this approach was introduced by Flesch et al. (1995), based on (an ensemble of N) backward trajectories,

$$\begin{aligned} Q^{(est)} &= \frac{U\, C_P}{n} \\ n &= \frac{1}{N}\sum_i \frac{2}{w_{0i}/U} \end{aligned} \qquad (2)$$

where U is a reference windspeed (whose explicit inclusion renders the "magic number" n dimensionless). The summation runs over all "touchdowns" of trajectories on the source, and w_{0i} is the magnitude of the vertical velocity of the i^{th} touchdown.

We performed experiments to test the accuracy of the backwards Lagrangian stochastic ("bLS") procedure, by releasing methane from a 6m x 6m source on ground, and detecting line-average concentration nearby using lasers. Two papers at this conference describe the outcome: paper **9.8** covers the case where the source was on open terrain (undisturbed winds), and this paper covers the case where the source lay within the windbreak described in paper **2.5**. Here we enquire whether the naive use of inverse dispersion (eqns 1, 2), using a dispersion model appropriate (only) for *undisturbed* surface layer winds, would have some value even if applied to estimate a source in a region of *disturbed* winds (Fig. 1). It is important to emphasize that, even in the horizontally-uniform case, source diagnosis for short periods (15-30 mins) by "inverse dispersion" carries an uncertainty of (roughly) $\pm 25\%$ (the bias when successive short-term estimates are summed is smaller). This is because the micro-meteorological state (deduced from observations) and the dispersion model are built on a set of *assumptions* about the atmosphere: eg. Monin-Obukhov "universal" functions ϕ_m, ϕ_h for wind and temperature profiles, the ratio σ_w/u_*, and other "universal" constants.

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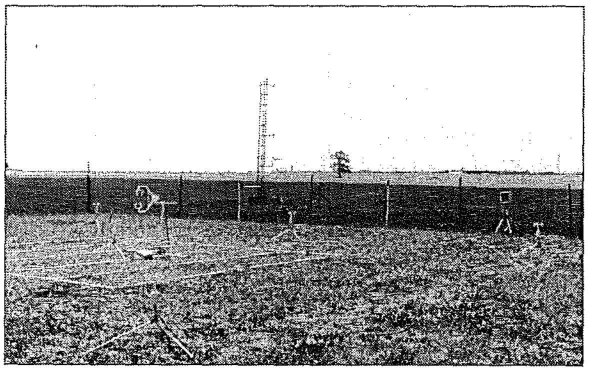

Figure 1: Gas source within windbreak, Elleslie, Alberta. Retro-reflector of methane laser is visible.

2 Tracer Experiment

We released methane from a gas cylinder at a constant rate ($Q^{rot} = 20 - 40$ litres per minute) that was monitored by a rotameter (we think an uncertainty of no more than $\pm 10\%$ applies to Q^{rot}). The tracer flowed into a $6m$ x $6m$ manifold constructed from $1"$ (id) pvc, and escaped through holes drilled at 1m intervals along the pipe. This array of point sources approximates a continuous area source. Trials described here took place with the source enclosed symmetrically within a porous plastic windbreak fence (side-length $D = 20m$, height $h = 1.25m$, resistance coefficient $k_r = 2.4$).

Two laser gas detectors were operated, at ranges up to $100m$, and using pathlengths from about $20 - 100m$; path-height $z_p \approx 1m$. The noise-level of these detectors was $\sim 1[ppm\ m]$, ie. $0.01ppm$ for a $100m$ path. During a typical trial, gas was released for about 90 minutes, preceded and followed by periods when the lasers determined background concentration (C_b). A GPS was used to determine all positions, eg. endpoints of laser paths relative to the source, etc.

3 Inverse dispersion $\Rightarrow Q^{(est)}$

Fig. (2) is a schematic of run **F3** (May 31, 2001). Trajectory calculations for eqn (2) used Thompson's

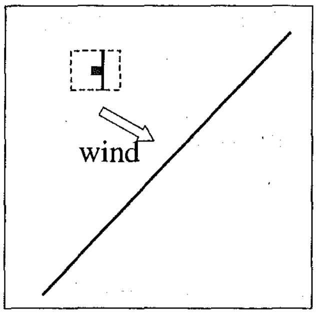

Figure 2: Configuration of run **F3**. Solid square is the source (sidelength $D = 20m$); dashed line is the windbreak; solid lines are laser paths. (Not exactly to scale).

(1987) well-mixed Lagrangian stochastic model for 3-d Gaussian vertically-inhomogeneous turbulence. The laser path was divided into 100 segments; an ensemble of backward trajectories calculated for one such segment serves, by simple displacement, to determine the touchdown field for each other segment.

Wind speed and direction were rather steady during this period (Table 1)[2]. Figs. (3, 4) show that the

Table 1: Run **F3**: 15 min means.

β	$U_2, m/s$	$u_*, cm/s$	L, m	σ_w/u_*	z_0, cm
329	6.26	49	-91	1.10	1.2
332	6.17	49	-98	1.11	1.2
329	6.45	49	-98	1.12	1.0
326	6.92	54	-110	1.15	1.2
327	7.81	63	-113	1.11	1.4
323	6.67	55	-74	1.11	1.4
315	6.14	49	-53	1.10	1.2
306	6.89	57	-72	1.15	1.5

estimation derived from the far laser is reasonable; 15 min values are within $\sim$ 25% of the rotameter value, and the two hour mean flux is within 5%. Other runs yielded similarly good estimates ($\pm \sim$ 25%) from the far laser, indicating that provided $Q^{(est)}$ is inferred from concentration observed "far enough" from the flow disturbance, the technique can be applied with an expectation of *about* the same accuracy as if the source was on open land. Of course the "far enough" is ambiguous: here the faraway laser was about $2D$ $(= 32h)$ from the flow disturbance.

In interpreting the accuracy of the inverse dispersion technique in disturbed flow, one needs to bear in mind the difficulty of providing any better technique, by which it might be judged. These unexpectedly good results, despite severe non-homogeneity of the flow, imply it may be possible to extend the technique to sources around farm buildings, hedges, and such natural disturbances.

[2]From tower profiles, except σ_w/u_* from 3d sonic on tower, post-rotation. U_2 is windspeed at $2m$.

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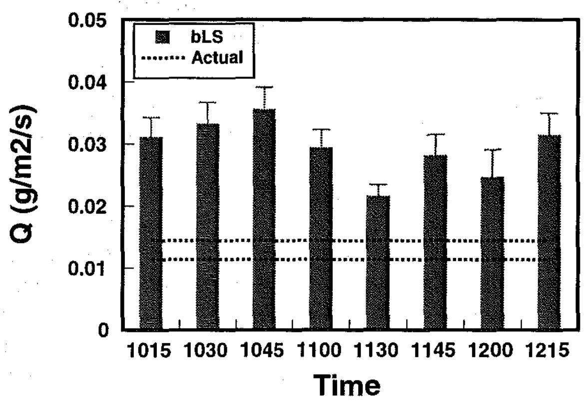

Figure 3: Estimated source strength based on line-average concentration from the nearby laser.

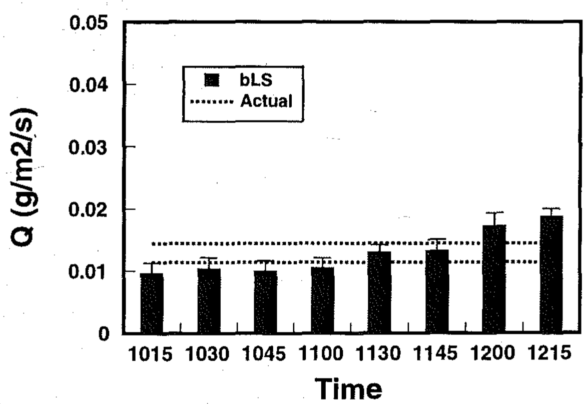

Figure 4: Q deduced from the far laser.

References

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