2008 ROADWAY SOUND BARRIER ATMOSPHERIC TRACER STUDY

Kirk L. Clawson[1], R. Eckman[1], T. Pierce[2], R. Carter[1], D. Finn[1], S. Perry[2], V. Isakov[2], and J. Rich[1]

[1]National Oceanic and Atmospheric Administration
Air Resources Laboratory
Field Research Division
Idaho Falls, ID 83402

[2]U.S. Environmental Protection Agency
Atmospheric Modeling and Analysis Division
Atmospheric Exposure Integration Branch
Research Triangle Park, NC 27711

Introduction

A roadway toxics dispersion study was conducted during the month of October at the NOAA Tracer Test Facility on the U.S. DOE's Idaho National Laboratory (INL) near Idaho Falls, ID. The Field Research Division of NOAA, in conjunction with the Atmospheric Modeling and Analysis Division of the U.S. EPA, conducted the experiment. The purpose of the study was to document the concentrations of an intentionally released atmospheric tracer behind a roadway sound barrier in various conditions of atmospheric stability. The results will augment those of a wind tunnel study conducted by the U.S. EPA in a similar manner to this field study. The experiment was conducted in the pristine environment of the INL to enable clear, easy, and unambiguous interpretation of the data. Simultaneous tracer concentration measurements with bag and real-time samplers were made from a sampling grid downwind from two 54m line sources; one with 90m long 6m high mock sound barrier-induced turbulence and the other without the barrier. Sonic anemometers were employed to measure the barrier-induced turbulence. Supporting meteorological measurements came from infrastructure already in place at the test site.

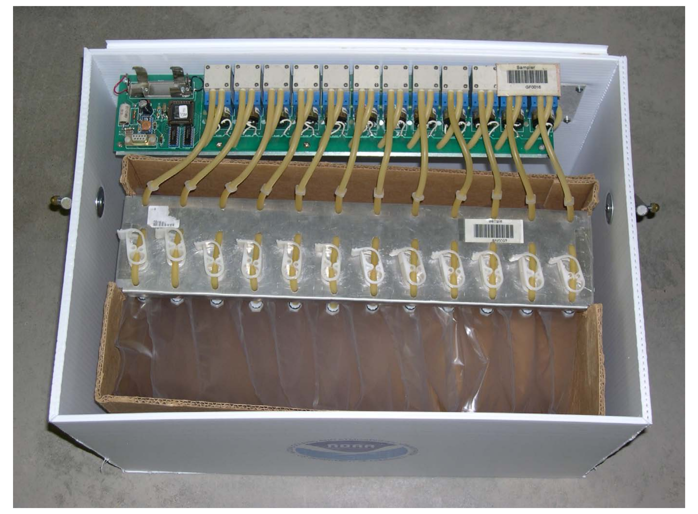
Roadway Experiment Highlights

- Conducted at the NOAA Tracer Test Facility on the INL in October 2008 to study dispersion of vehicle emissions downwind of road side sound barriers.
- SF_6, a non-toxic tracer, was released and tracked in a sampling grid downwind from a mock sound barrier 6m tall and 90m in length.
- SF_6 was also released and tracked on an identical non-barrier sampling grid.
- Tracer was released continuously for 3-hours at rates of 0.02-0.05 g s^{-1} from two 54m line sources.
- A dense tracer sampling grid was utilized to guide future modification of the AMS/EPA Regulatory Model AERMOD for roadway vehicle emissions.
- One hundred thirty-two air samplers and 2 real-time continuous analyzers were used to measure tracer.

Real-time Continuous Analyzers

- Measures SF_6 concentration from 10 to 20,000 pptv with a response time of about 1 second.
- Built-in calibration system and quality control checks ensure data quality.
- Fits easily in the seat of a vehicle.
- Ideally suited for the measurement of plume structure such as cross wind plume profiles.
- Each sampling grid was entirely traversed every 15-minutes.

Programmable Integrating Bag Samplers



- Sequentially fills 12 Tedlar® bags with tracer-laden air which are later analyzed for tracer concentration with gas chromatographs.
- Measures SF_6 from 1 to over 1,000,000 pptv.
- Complete quality control program is used to ensure accurate measurements.
- Sampling times are completely programmable.
- Results reflect average concentration over the programmed sampling time.
- A sampling time of 15-minutes per bag was used for this study.
- Samplers were placed on metal fence posts 1.5m AGL.

Tracer Release System

- A small amount of stable, non-toxic, invisible, odorless, and easily dectectable SF_6 tracer was released into the air.
- Mass flow controller controls the tracer release rate.
- Computer monitors flow rates and leaks in the system.
- Weight loss from the bottle determines the total amount of tracer released.
- Dual release mechanisms were used for the barrier and non-barrier sampling grids.
- Release rates during each test were constant for the entire test.
- Release rates ranged between 0.02 and 0.05 g s^{-1}.

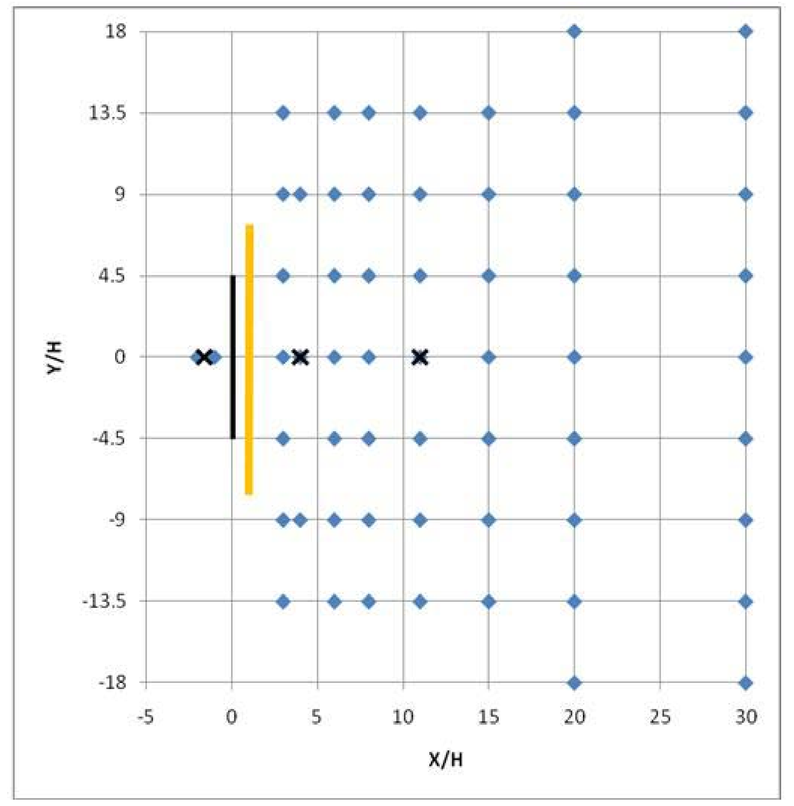
SF_6 Continuous Tracer Release Line

- Tracer was disseminated from 64 individual 31-gauge calibrated syringe needles.
- Release line was 54m in length and 1 meter above the ground.
- Release mechanism was designed as a binary tree system to ensure equal flow rates at every syringe needle.

Sonic Anemometer Array

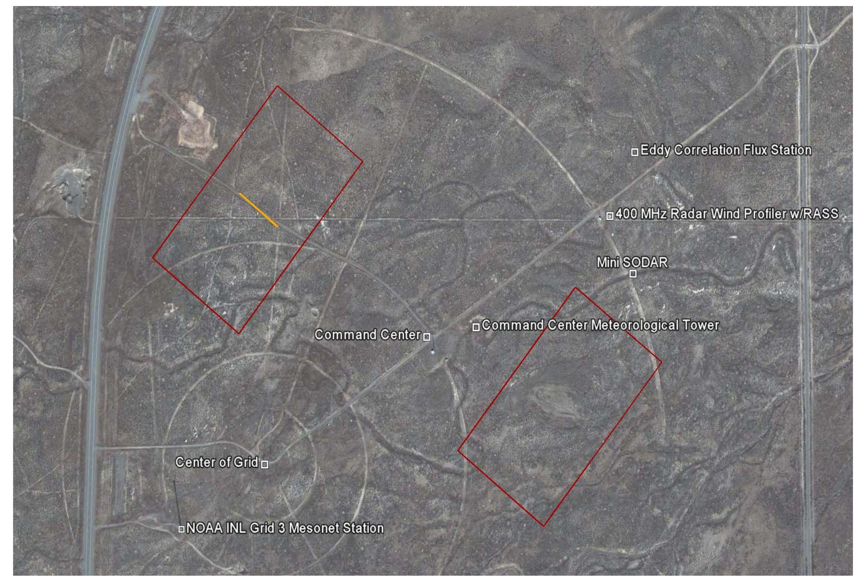
- Six 3-d sonic anemometers were deployed to measure the turbulence of the study domain:
  - 3 located on a tower behind barrier measured the vertical profile of the turbulence field.
  - 1 located at the flow reattachment point downwind of the barrier.
  - 1 located upwind of the barrier.
  - 1 located on the non-barrier grid to measure the approach flow.
- Data were collected at 10 Hz.

Sampling Grid Schematic



- Schematic representation shows the barrier (orange line), the tracer release line source (bold black line), sonic anemometers (**X**), and bag samplers (blue diamonds).
- Sampler grid spacing was based on multiples of the sound barrier height H, where H=6m.

Roadway Study Domain

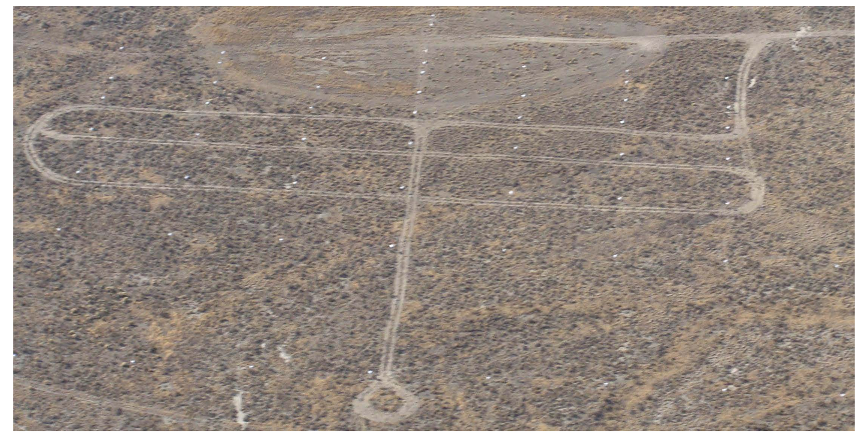


- Sampling grids were constructed at the existing NOAA/INL Tracer Test Facility.
- Barrier sampling grid is indicated by upper left red box.
- Non-barrier sampling grid is indicated by red box in the lower right corner of the photo.
- Terrain is mostly flat but is bisected by ancient dry creek beds up to 1.5m in depth.
- Vegetation is sparse and consists of mainly of sagebrush and rabbit brush less than 1m in height.

Aerial View of Barrier Grid

- Tracks in the aerial views above/below indicate the path of the real-time continuous analyzers.

Aerial View of Non-Barrier Grid



Aerial photos courtesy of Thomas Strong.

Preliminary Results

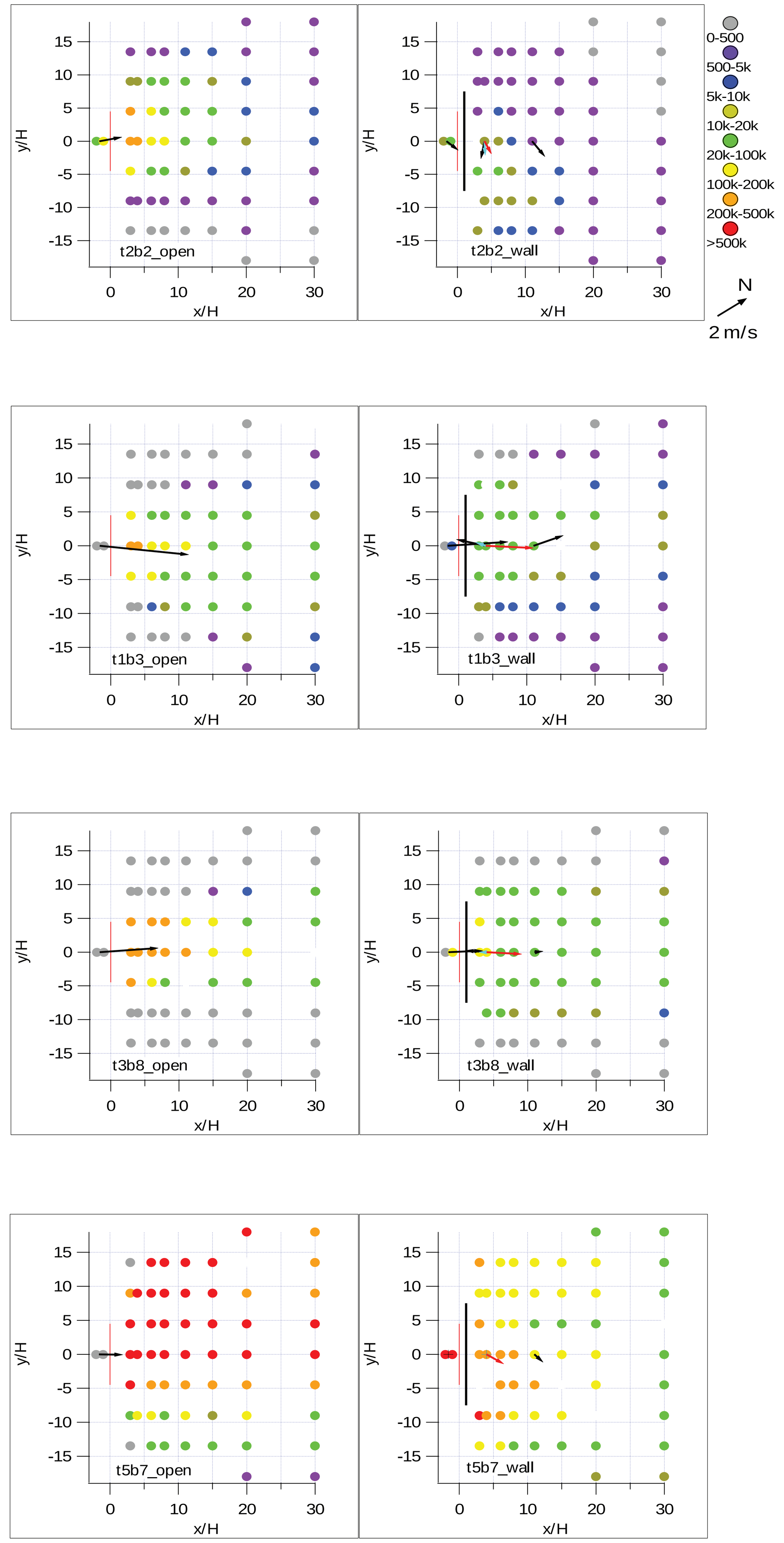
Non-Barrier Grid | Barrier Grid

Unstable

Neutral

Weakly Stable

Strongly Stable



- Colored dot plots indicate normalized concentrations.

Roadway Summary

- There was invariably a concentration deficit in the wake zone of the barrier with respect to concentrations at the same grid locations on the non-barrier side. This was due to (1) vertical movement and dispersion forced by the barrier, (2) turbulence above the wake zone generated by shear flow across the barrier enhancing turbulent dispersion, and (3) horizontal plume spread (with or without edge effects).
- Lateral dispersion and horizontal plume spread were significantly greater on the barrier grid than the non-barrier grid.
- The areal extent of the concentration footprint downwind of the barrier was a function of atmospheric stability with the footprint expanding as stability increased.
- The magnitudes of the normalized concentrations were a function of atmospheric stability. Concentrations increased on both the barrier and non-barrier grids as atmospheric stability increased.
- The barrier decelerated and deflected the approach flow.
- The barrier tended to trap high concentrations in the "roadway" at low wind speeds, especially in stable conditions.
- The anemometers on the tower array in the wake zone provided strong evidence for the presence of a rotor in the wake of the barrier and a higher turbulence region above the wake zone induced by shear across the top of the barrier.
- Edge effects ranged from negligible or minor to severe. The importance of the edge effects was related to mean wind direction, the extent of wind meander, wind speed, and atmospheric stability.

Recent Urban Tracer Studies

- MID05 - Urban dispersion in Midtown Manhattan in 2005.
- Pentagon Shield - Urban dispersion at the Pentagon in 2004.
- Joint Urban 2003 - Urban dispersion in the compact central business district of Oklahoma City in 2003.
- Urban 2000/VTMX - Nocturnal urban dispersion in the complex terrain of Salt Lake City in 2000.