**3.13** JOINT URBAN 2003 VERTICAL $SF_6$ REAL-TIME ANALYZER AND TIME-INTEGRATED SAMPLER DATA CHARACTERISTICS

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## 1. INTRODUCTION

The threat of a terrorist releasing a toxic gas in an urban environment continues to be a concern to emergency planners, especially after the events of September 11, 2001. To help prepare for such an event, transport and dispersion models are being used in urban settings to assist and guide emergency planning. However, urban environments add an additional level of complexity to transport and dispersion modeling. Models must accurately predict what will happen in real-world situations, so that the emergency plans will be efficacious. Model accuracy is determined through the model validation process, which relies primarily on data acquired from field trials using atmospheric tracers.

Joint Urban 2003 (JUT) was conducted to expand a database of major urban atmospheric tracer studies for model validation purposes. That database incorporates measurements at single building, multi-building, urban, and suburban scales. An overview of the project was presented by Allwine et al.(2004). The month-long field study was funded by the U.S. Departments of Defense (through the Defense Threat Reduction Agency) and Homeland Security. It involved researchers from several national laboratories, universities, and government agencies including the NOAA /ARL Field Research Division (FRD), making for a rather large experiment. FRD alone fielded a mini-sodar, 150 time-integrated 12-position bag $SF_6$ samplers, 10 real-time $SF_6$ analyzers, and the $SF_6$ release mechanism. The equipment was deployed to support several different objectives. This paper will focus on the results obtained from paired surface and elevated real-time analyzers and bag samplers.

## 2. MATERIALS AND METHODS

JUT consisted of six daytime and four nighttime intensive experiments that were conducted in Oklahoma City, OK during June and July 2003. The 10 intensive observation periods (IOP) involved the release and sampling of the inert, non-toxic atmospheric tracer gas $SF_6$ (sulfur hexafluoride) in combination with an extensive array of meteorological equipment. The daytime IOPs were generally conducted from 0900-1600 hours CDT, while the nocturnal IOPs were generally conducted from 2300-0600 hours CDT. The tracer was disseminated both continuously and in puffs. An IOP consisted of three 30-minute continuous releases, each separated by 90 minutes, and either followed or preceded by 4 puff (instantaneous) releases in 20-minute intervals. Continuous release rates ranged from 2-5 g $s^{-1}$ and the puff releases ranged in size from 300-1000 g. The release rate of $SF_6$ was monitored throughout each experiment and was within 5% of the desired rate. Three release sites, shown in Fig. 1, were: 1) near the intersection of Robinson and Sheridan and denoted as Botanical, 2) near the intersection of Broadway and Main and denoted as Westin, and 3) midway between Robinson and Broadway on Park and denoted as Park. The tracer was disseminated at 1-2 m AGL.

Atmospheric $SF_6$ tracer concentrations were monitored downwind of the dissemination site by both

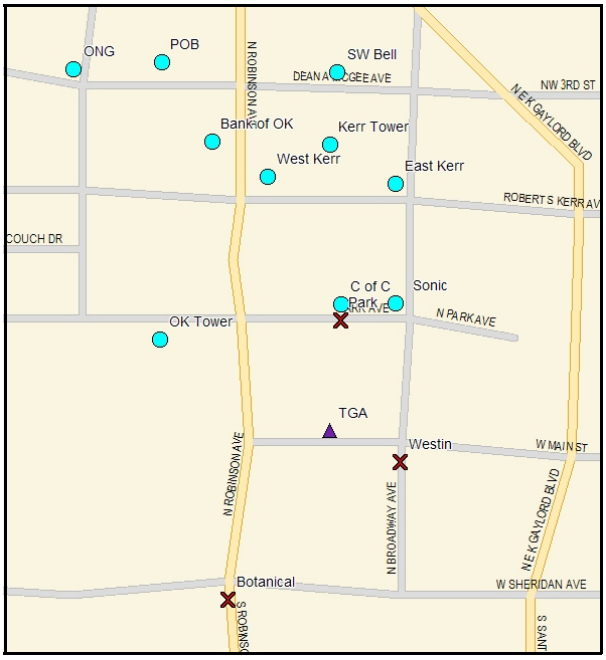


Figure 1. Locations of the tracer release sites (red x), roof-top real-time analyzer (purple triangle), and roof-top bag samplers (aqua dot).

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mobile and fixed real-time $SF_6$ analyzers and by time-integrated $SF_6$ bag samplers. The FRD-built real-time $SF_6$ analyzer (Fig. 2) makes measurements of atmospheric $SF_6$ concentrations with a response time of just under one second. The rapid response time and mobile nature of the analyzers make them ideally suited for measurements of plume widths and structure. They have been utilized in experiments measuring both across wind (e.g., Clawson et al, 2001) and along wind (e.g. Bowers et al., 1994) diffusion parameters commonly used in transport and dispersion models, and in other recent major urban tracer studies (e.g., Allwine et al, 2002). The heart of the system is the TGA–4000 (Tracer Gas Analyzer) manufactured by Scientech Inc. of Pullman, WA.


Figure 2. FRD continuous mobile $SF_6$ tracer gas analysis system installed in the rear seat of an SUV, showing computer controlled TGA-4000 (bottom) and calibration gas container (lower right).

The TGA-4000 real-time $SF_6$ analyzer is a fast response instrument designed specifically to measure the concentration of $SF_6$ in ambient air. The TGA–4000 uses an electron capture detector (ECD) to detect $SF_6$. The detection limit of the ECD is about 5 parts per trillion volume (pptv). The TGA-4000 signal along with real-time GPS position, instrument temperatures, and ambient pressure are collected by a laptop computer at the rate of 2 Hz. The computer stores the data for later post-processing and simultaneously displays the TGA-4000 signal for operator interpretation and control. Using this display, the operator determines the plume concentration (and position, if mobile) by using software controls to "mark" the beginning and ending of the plume trace. Run-time quality control (QC) outputs allow the operator to monitor the performance of the system.

Ten real-time analyzers were installed in vans and deployed during JUT (Fig. 3), but only two were paired vertically to simultaneously monitor both the ground-level and elevated tracer plume structure. These two analyzers were deployed midway between Robinson and Broadway on Main (Fig 1) with the elevated analyzer placed on top of a 7-story parking garage.

Figure 3. FRD real-time $SF_6$ analyzer van fleet deployed during JUT.

The time-integrated bag samplers are also a FRD invention. Each sampler consists of 12 microprocessor-controlled air pumps for sequentially filling 12 bags using the identical fill time for each bag. The sampler is contained in a weatherized waxed cardboard box measuring 61 cm x 41 cm x 33 cm (Fig 4.) and powered by a single D-cell battery. Inside the sampler box is a smaller cardboard box called a cartridge, which contains the 12 1-liter bags made of Tedlar. The cartridge is placed inside the sampler box and connected to the sampler mechanism by latex rubber tubing. With the cover, the unit weighs approximately 4 kg. The samplers have been used for many years and have been extensively tested.

Ten of the bag samplers were placed on roof-tops to monitor elevated tracer plume concentrations. Many of these roof-top samplers were in close proximity laterally to a paired set of ground-level samplers to permit simultaneous comparison of elevated and ground-level concentrations. The roof-top locations are illustrated in Fig. 1 and were placed in the following locations:
Oklahoma Tower (OK Tower)
Chamber of Commerce (C of C)
Sonic Building (Sonic)
Bank of Oklahoma (Bank of OK)
West Kerr-McGee Complex (West Kerr)
Kerr-McGee Tower (Kerr Tower)
East Kerr-McGee Complex (East Kerr)
Oklahoma Natural Gas Building (ONG)

Figure 4. Time-integrated $SF_6$ bag sampler with installed 12-bag cartridge. D-cell battery is shown in lower-right.

Old Post Office Building (POB)
Southwestern Bell Building (SW Bell)

## 3. RESULTS AND DISCUSSION

A typical daytime $SF_6$ concentration trace from a puff release as a function of time obtained from the real-time analyzers is shown in Fig. 5. The trace is from IOP 5, which was conducted in the afternoon of 12 July. Skies were mostly clear, the air temperatures was approximately 33 C, and the wind speed was around 4 m $s^{-1}$. The tracer material arrived at the site (about 200 m downwind) about 2 minutes after dissemination of the puff at both the surface and elevated instruments. The peak concentration of 9,000 pptv occurred at the elevated instrument within one minute after the material was first detected. The concentration rapidly declined until the material was essentially zero about 6 minutes after arrival.

The peak concentration at the surface was measured in the second minute after the arrival of the material with a concentration of about 7,000 pptv. The concentration also rapidly declined from the maximum, but bits and pieces of the puff continued to be visible until about 9 minutes after first detection. The assumption is that the tracer material gets caught in local eddies produced by trees, buildings, and so forth as it is advected with the wind. These shards of the puff continue to be detected much longer than would be expected in open terrain. The trace certainly is not Gaussian in shape.

A typical nocturnal $SF_6$ concentration trace from a puff release is shown in Fig. 6. The trace is from the early morning of 18 July before sunrise. The skies were mostly clear, air temperature was approximately 28 C, and the wind speed was around 4 m $s^{-1}$. The tracer material began to arrive at the surface about 3 minutes after dissemination, with a peak concentration of about 6,750 pptv about 3 minutes after arrival. Detectable amounts of tracer were still visible until about 13 minutes after the material first arrived.

The elevated sensor did not detect any tracer until almost 7 minutes after dissemination. The peak concentration of about 3,000 pptv occurred about 3-4 minutes after first detection, and remained at detectable levels until the end of the 20-minute measurement window. The elevated peak concentration was about 1/3 to 1/2 that of the surface peak concentration.

From these observations, it is clear that the nocturnal puff behaved much differently from the daytime puff. Arrival and departure times were much different and the relationship between the surface and elevated measurements were also very different. The real-time concentration traces also exhibit very different structure.

The time-integrated bag samplers were only used during the continuous 30-minute releases. A typical plume concentration time-history is shown in Fig. 7 from the samplers placed at the base and on the top of the 31-story Kerr-McGee tower. The tower is approximately 450 m downwind from the release site.The gaps in the concentration trace are when the sampler was in a quiescent mode waiting for the next puff to begin. The IOP 6 release was another daytime release with similar conditions as for IOP 5. At times, the rooftop concentration exceeded the concentration measured at ground level. This also shows that the elevated and surface concentrations are quite similar and indicates extensive vertical mixing.

## 4. REFERENCES


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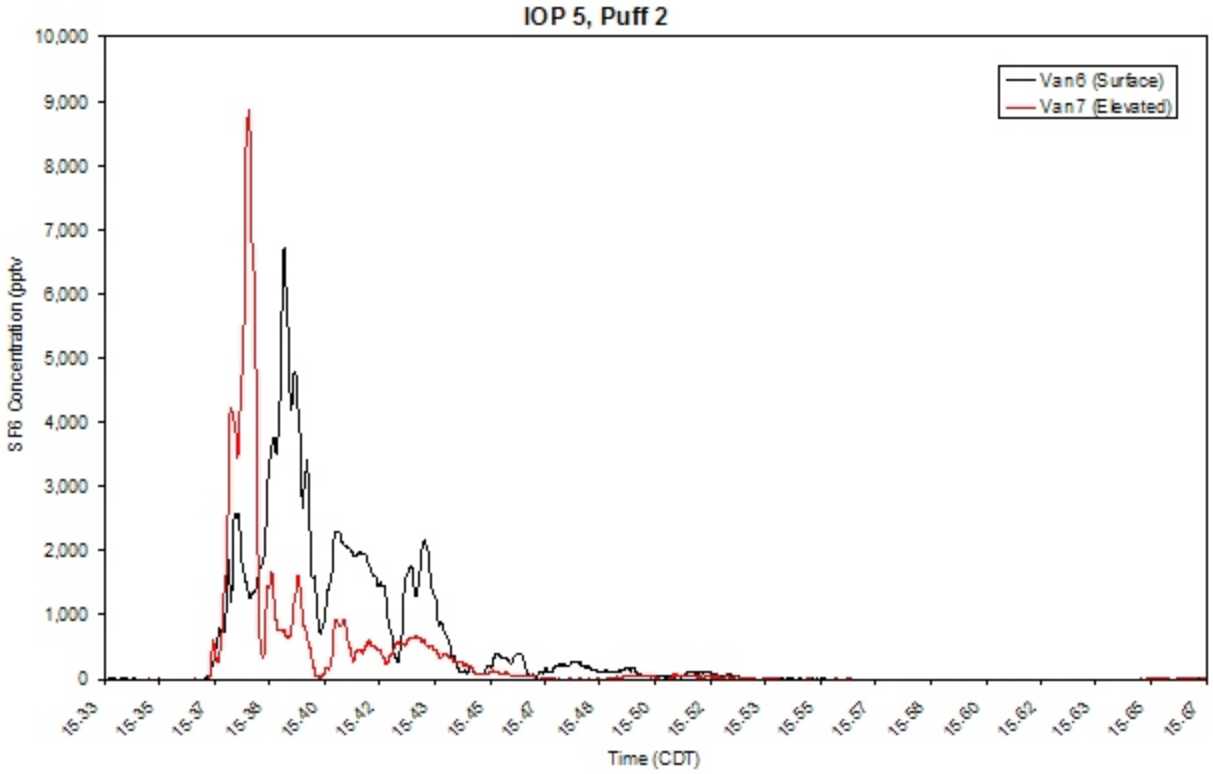


Figure 5. Surface and elevated $SF_6$ concentrations for a typical daytime surface puff release.

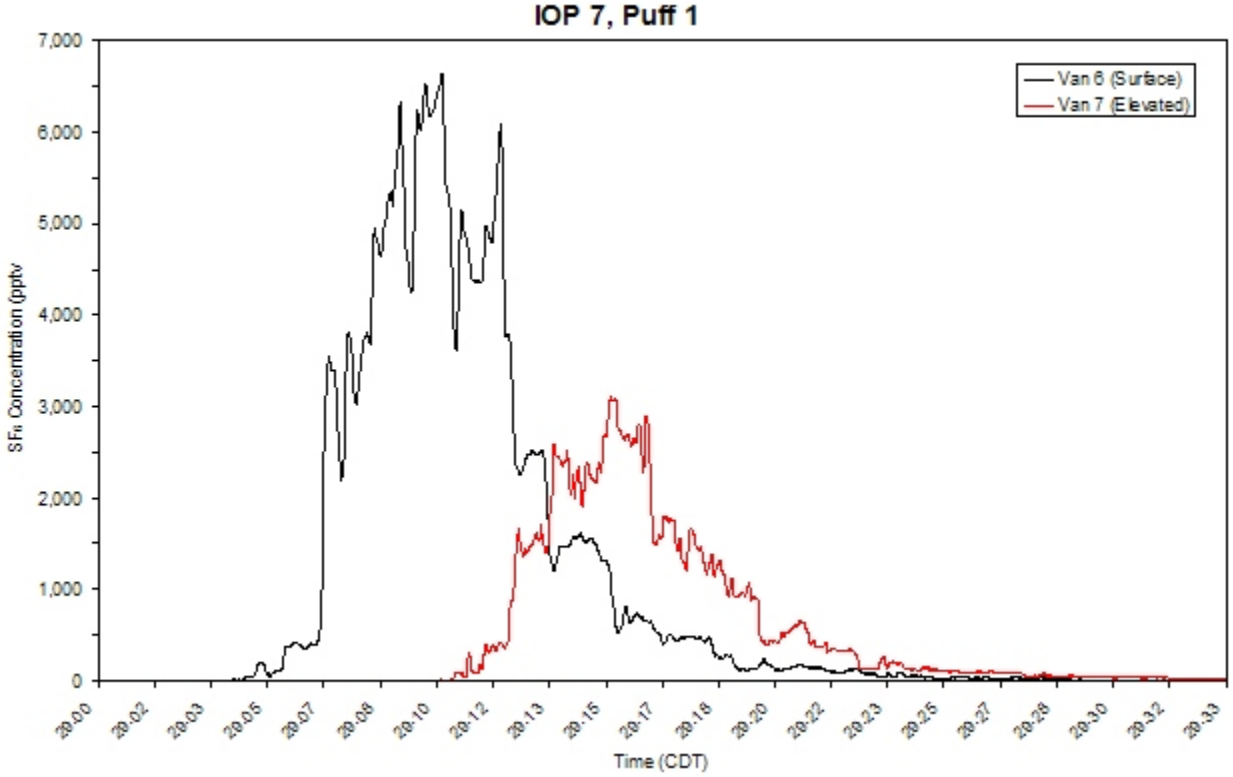


Figure 6. Surface and elevated $SF_6$ concentrations for a typical nocturnal puff release.

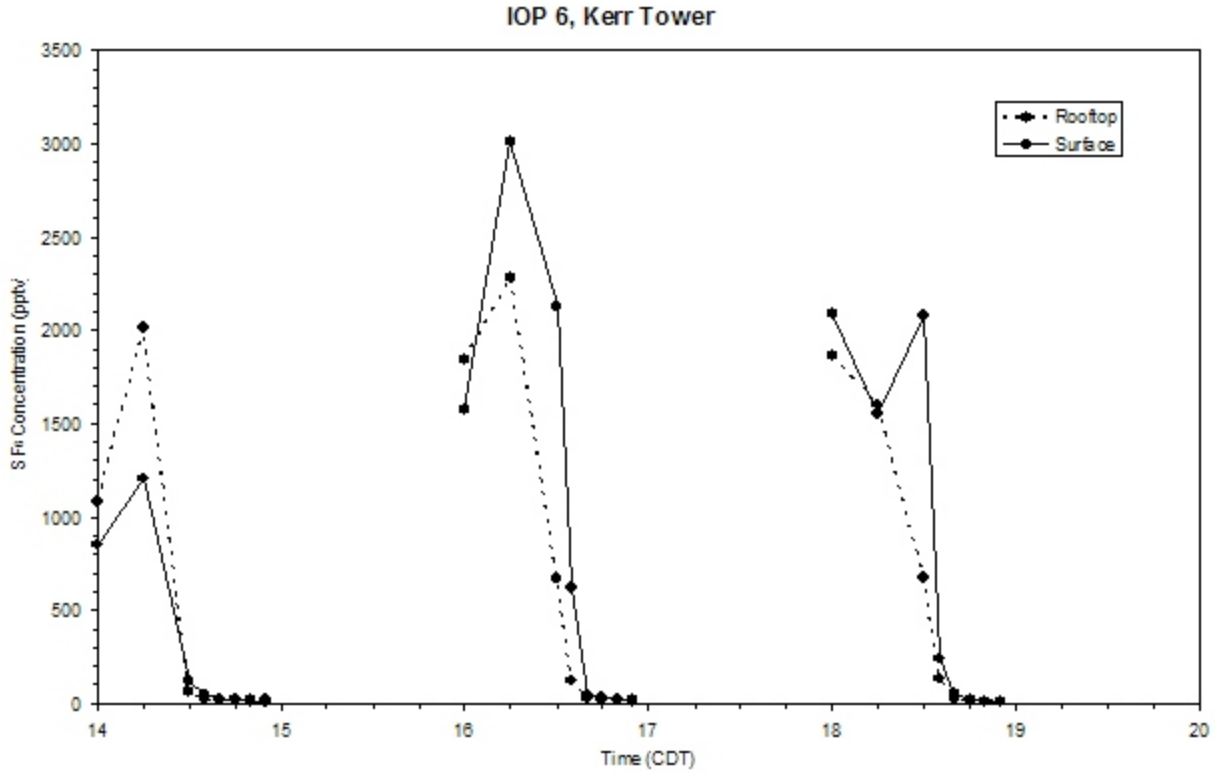


Figure 7. Surface and elevated time-integrated $SF_6$ concentrations from bag samplers during a 30-minute continuous dissemination.