EPA/600/A-97/027

A Mobile Meteorological Monitoring System for Use in Open Burning and Open Detonation Activities

Gennaro H. Crescenti[1]
Atmospheric Sciences Modeling Division
Air Resources Laboratory
National Oceanic and Atmospheric Administration
Research Triangle Park, North Carolina 27711

Brian D. Templeman
Cooperative Institute for Research in Environmental Sciences
University of Colorado
Boulder, Colorado 80309

ABSTRACT

A mobile meteorological monitoring system of *in situ* and remote sensors has been designed and constructed to characterize the atmospheric boundary layer from the surface up to 2 to 3 km at facilities which conduct open burning (OB) and open detonation (OD) of surplus (demilitarized) military munitions. Surface layer measurements include horizontal wind speed and direction, air temperature, relative humidity, net radiation, barometric pressure, precipitation, and turbulence. Vertical wind profiles are acquired by a Doppler sodar and a radar wind profiler. The sodar and radar work in unison as a radio acoustic sounding system (RASS) to acquire virtual air temperature profiles. A ceilometer has been included for estimation of the mixed layer height. These remote sensors are mounted on a flat bed trailer which allows easy transport from one OB/OD facility to another. All of the computers used for data acquisition are networked together into a primary computer. The meteorological data are used by an OB/OD for predicting transport and dispersion of emissions released into the atmosphere.

INTRODUCTION

During the Cold War the United States military accumulated a vast arsenal of warfare materials (munitions, propellants, pyrotechnics, rocket motors, manufacturing waste) which are increasingly old and unstable. Now that the Cold War has ended, the U. S. is faced with the task of disposing these energetic materials in an environmentally safe manner. Disposal of the demilitarized stockpile will be a momentous undertaking. The current surplus inventory is estimated to be at 500,000 tons and growing rapidly at a rate of 40,000 tons per year (U. S. Army, 1995). These materials are distributed throughout the country at several hundred Department of Defense and Department of Energy installations.

The most common disposal method currently in use is open burning (OB) and open detonation (OD). OB/OD disposal techniques are a relatively simple and cost effective means for

---

[1] On assignment to the National Exposure Research Laboratory, U. S. Environmental Protection Agency.

stockpile reduction. However, these activities can generate air pollutants such as SO_2, NO_x, CO, particulates, metals, cyanides, and volatile and semivolatile organic compounds. In addition, shrapnel and noise from an OD is a cause for concern. Any facility which intends to use OB/OD disposal methods must meet permit requirements under Part 264, Subpart X of the Resource Conservation and Recovery Act (U. S. EPA, 1993). To obtain a Subpart X permit, a facility must provide information on the materials being destroyed, the type and quantity of pollutants being released, a description of how these pollutants will be dispersed in time and space, and an assessment on the potential impact on human health and the surrounding ecosystem by these emissions both on a short-term and long-term basis. A Subpart X permit is issued by an Environmental Protection Agency (EPA) Regional Office only if the facility can demonstrate that the impact from OB/OD activities poses no significant threat to human health and the surrounding ecosystem. Very few Subpart X permits have been granted. This is due, in part, to the lack of an EPA approved model specifically designed to simulate OB/OD transport and dispersion. In many instances, the facility applying for a permit does not have enough data to demonstrate compliance.

The Strategic Environmental Research and Development Program (SERDP) has funded EPA's National Exposure Research Laboratory (NERL) and the National Oceanic and Atmospheric Administration's (NOAA) Environmental Technology Laboratory (ETL) to develop an OB/OD air pollution dispersion model and a mobile meteorological observing platform which will be used to acquire the necessary information needed for obtaining a Subpart X permit. Weil et al. (1995, 1996a, 1996b) are developing a Gaussian puff model which considers source emissions, plume rise, transport and dispersion from either an OB or OD. Mitchell et al. (1996) discuss the use of computational fluid dynamics to model source characterization of an OB/OD. The mobile meteorological monitoring system will provide a detailed characterization of the structure and dispersive state of the atmospheric boundary layer (ABL). Those data acquired by the mobile monitoring system will also be used by the model for predicting transport and dispersion of emissions released by an OB or OD into the atmosphere. This paper describes the meteorological monitoring system.

SENSOR DESCRIPTION

Because OB/OD plumes rise quickly, it is important to accurately characterize the state of the ABL. In order to accomplish this, a suite of *in situ* and remote sensors are used to describe the vertical structure of the atmosphere from the surface up to 2 to 3 km. The original design specifications for a measurement system were presented and considered at a workshop in February 1995 (Banta, 1996). A consensus was reached on the measurements needed to characterize the ABL and for input into the OB/OD dispersion model. The system was designed to be mobile so that it could be easily moved from one OB/OD site to another with a minimal amount of time and effort.

Tower-based *in situ* sensors are used to acquire surface layer measurements while a suite of remote sensors, mounted on a flatbed trailer, are used to obtain vertical profile data. The accompanying electronics and data acquisition systems are located in an enclosed mobile trailer.

In Situ Sensors

A 20-m open-lattice aluminum tower will serve as a measurement platform for a number of *in situ* sensors. An R. M. Young wind monitor is used to measure the horizontal wind speed and direction at 10 m. A Vaisala HMP-35A probe is used to measure air temperature and relative humidity at 2 m. Net radiation is acquired with a Radiation Energy Balance Systems net radiometer. A Vaisala PTB-101B transducer is used for measuring barometric pressure while precipitation data is acquired by a Texas Electronics tipping bucket rain gauge. A Campbell Scientific CR-10 data logger is used to interrogate these sensors and log their data as 15-min values. These data are telemetered via a radio frequency (RF) line-of-site link to the "hub" computer on regularly scheduled basis (typically once per hour) or on demand.

Two Metek sonic anemometers are mounted on the tower at 5 and 20 m. These fast response instruments acquire mean, variance, and covariance of the three-component wind velocity and virtual air temperature. Using eddy correlation techniques, these sensors can also determine turbulence parameters such as the kinematic heat and momentum flux, friction velocity, and Monin-Obukhov length. Each sonic transmits its data by an RS-232 serial line to a computer.

The monitoring system is designed to incorporate a number of ancillary tower systems where complex terrain settings demanded a better representation of the surface layer wind field. Should this need arise, a sufficient number of 10-m towers are deployed. In this case, each tower is equipped only with an R. M. Young wind monitor and a Vaisala air temperature and relative humidity probe. A Campbell Scientific CR-10 data logger is used to acquire these data and the same RF telemetry link is utilized for transmission of this information to the hub computer.

Remote Sensors

Two types of profilers are used to acquire wind profile data. The first is a Radian 924 MHz phased-array Doppler radar wind profiler. The range of the radar is approximately 2 to 4 km with a resolution of 60 or 100 m (depending on mode of operation). The radar acquires estimates of the refractive index structure parameter. This quantity is a direct measurement of the turbulent intensity of humidity fluctuations in the ABL and is useful for estimating the mixed layer height. The second profiler is a Radian phased-array Doppler sodar. This sensor is used to acquire wind profiles in the first several hundred meters of the planetary boundary layer. The sodar range is approximately 500 to 1000 m with a resolution of 30 m. The backscatter information acquired by the sodar is directly related to the temperature structure function. This measurement is useful in depicting inversion layers and other regions were temperature gradients exist.

By combining the radar and sodar, a radio acoustic sounding system (RASS) was added to acquire virtual air temperature profiles. The range of the RASS is 1 to 1.5 km with a resolution of 60 or 100 m. This RASS differs from the more traditional systems which utilize four separate acoustic sources surrounding the radar. In this configuration, the sodar acts as the acoustic source. The phased-array design allows the acoustic beam to be steered upwind which optimizes data capture efficiency. During the first 25 min of a 30-min sampling cycle, the radar and sodar operate independently from each other acquiring wind profiles and backscatter data. During the last 5 min, the RASS mode is initiated and the sodar and radar work together to determine the temperature profile.

A Vaisala CT25K ceilometer is used to estimate the aerosol backscatter profile and cloud base height from the surface to about 4 km with a 15-m resolution.

The sodar, radar, and ceilometer are mounted on a 7-m flatbed trailer (Fig. 1). The radar sits on the front end of the trailer with the sodar in the rear. The ceilometer resides near the back edge of the trailer. Leveling of the trailer and sensors is accomplished with seven jacks mounted along the sides and front of the trailer.

Assembly and evaluation of this integrated mobile meteorological monitoring system has been conducted at the Boulder Atmospheric Observatory (BAO) in Erie, Colorado (Kaimal and Gaynor, 1983). Meteorological measurements taken from the BAO 300-m tower have been used to establish the reliability of the upper-air data obtained by the remote sensors. In addition, this system has been used to acquire data in the Colorado Front Range region as part of a wind profiling network during the Denver Brown Cloud Study. These data have been made available on the internet at http://www7.etl.noaa.gov.

COMPUTER SYSTEMS

A substantial number of computer systems and accompanying electronics are needed for data acquisition and processing. The mobile system is designed to be modular and integrated. Thus, all of the electronics are sheltered in an enclosed trailer. The heated and cooled trailer is 2.4 m wide and 5.5 m long. The procurement of a large trailer was necessary in the event more electronics were needed for additional meteorological sensors.

A depiction of the measurement system is shown in Fig. 2. The radar and sodar are each operated by their own 486 personal computer (PC). An RS-232 serial line between the radar and sodar computer enables these two systems to communicate in the RASS data acquisition mode. A third PC is dedicated to obtaining data from the ceilometer and two sonic anemometers using RS-232 serial lines. These three computers are networked into a "hub" computer using NodeRunner 2000/C self-describing Internet cards with LANtastic 7.0 network software. All tower-based measurements are relayed through a RF link which is hooked directly into the hub computer. A fifth computer (Silicon Graphics workstation) is linked to the hub using the same type of network connection. This computer is dedicated to the OB/OD dispersion model developed by Weil et al. (1995, 1996a, 1996b). Remote access into the hub computer is possible via telephone line and a high speed modem. Data from the hub computer can also be downloaded by File Transfer Protocol (FTP) through an Internet connection.

The hub computer employs a clock card to keep an accurate time. The hub periodically checks the four other computers and resets their respective clocks should they differ by more than 5 s. All of the computers and electronics require standard 110/120 AC, 60 Hz voltage. These systems are protected against power surges and outages with an uninterruptable power supply. The hub computer receives and records all meteorological data from each computer. These data are recorded on an internal hard disk and on an optical disk. The optical disk acts both as a backup mechanism as well as enabling dissemination of large volumes of information.

The hub computer also processes some of these incoming data. A real-time QA/QC editor (Weber et al., 1993) is employed to check for the quality and consistency of the radar wind profiler data. Mixed layer height determination algorithms (Angevine et al., 1994) have been incorporated which estimate the mixed layer height using data acquired by the radar, sodar, ceilometer and sonic anemometers. The hub computer also contain algorithms which will process the data in a format needed by the OB/OD model for real-time forecasts of plume transport and dispersion.

SUMMARY

A mobile meteorological monitoring system has been designed and constructed to characterize the atmospheric boundary layer at facilities which conduct open burning and open detonation of surplus military munitions. A suite of *in situ* and remote sensors is used to characterize the vertical structure of the atmosphere in the vicinity of an OB/OD from the surface up to 2 to 3 km. Surface layer measurements include horizontal wind speed and direction, air temperature, relative humidity, net radiation, barometric pressure, precipitation, and turbulence. Vertical wind profiles are acquired by a 924 MHz radar wind profiler and a Doppler sodar. A RASS is used to acquire virtual air temperature profiles. A ceilometer has been included to acquire information on aerosol backscatter and cloud base height. These ground-based remote sensors are mounted on a flatbed trailer which allows easy transport from one OB/OD facility to another. All of the computers used for data acquisition are networked together into a hub computer. The meteorological data are used by an OB/OD model for predicting plume transport and dispersion.

ACKNOWLEDGMENTS

The authors wish to express thanks to William Mitchell for his support. Special thanks to Alan Hoffman and Mac Wilkins for their reviews. This work has been supported by the Strategic Environmental Research and Development Program project 251.

DISCLAIMER

This document has been reviewed in accordance with U. S. Environmental Protection Agency policy and approval for publication. Mention of trade names or commercial products does not constitute EPA endorsement or recommendation for use.

REFERENCES

Angevine, W. M.; White, A. B.; Avery, S. K. "Boundary-layer depth and entrainment zone characterization with a boundary-layer profiler," Bound.-Layer Meteor. **1994** 68, 375-385.

Banta, R. M. *ETL/EPA workshop on open burning/open detonation (OB/OD)*, NOAA Tech. Memo. ERL ETL-267, Boulder, CO, 1996, 54 pp.

Kaimal, J. C.; Gaynor, J. E. "The Boulder Atmospheric Observatory," J. Climate Appl. Meteor **1983** 22, 863-880.

Mitchell, W. J.; Wilcox, J. L.; Biltoft, C.; Oran, E. S.; Boris, J. P. "Techniques to improve the environmental safety of OB and OD operations," in *Proceedings of the 89th Annual Meeting & Exhibition*, Air & Waste Management Assoc., Nashville, TN, 1996, paper 96-TA35.02.

U. S. Army. *Joint Demilitarization Study, Joint Ordnance Commanders Group.* Demil Technology Office, U.S. Army Defense Ammunition Center and School, Savanna, IL, 1995, 128 pp.

U. S. Environmental Protection Agency. *RCRA 40 CFR Part 264, Subpart X Draft Permit Writers Technical Resource Document.* Code of Federal Regulations, Title 40, Part 264, Office of the Federal Register, Washington, D. C., 1993.

Weber, B. L.; D. B. Wuertz; Welsh, D. C.; McPeek, R. "Quality controls for profiler measurements of winds and RASS temperatures." J. Atmos. Oceanic Technol.. **1993** 10, 452-464.

Weil, J. C.; Templeman, B.; Banta, R.; Mitchell, W. "Atmospheric dispersion model development for open burn/open detonation emissions," in *Proceedings of the 88th Annual Meeting & Exhibition*, Air & Waste Management Assoc., San Antonio, TX, 1995, paper 95-MP22A.05.

Weil, J. C.; Templeman, B.; Banta, R.; Weber, R.; Mitchell, W. "Dispersion model development for open burn/open detonation sources," in *Preprints of the 9th Joint Conference on the Applications of Air Pollution Meteorology*, Amer. Meteor. Soc., Atlanta, GA, 1996a, pp 610-616.

Weil, J. C.; Templeman, B.; Mitchell, W. "Progress in developing an open burn/open detonation dispersion model," in *Proceedings of the 89th Annual Meeting & Exhibition*, Air & Waste Management Assoc., Nashville, TN, 1996b, paper 96-TA35.01.

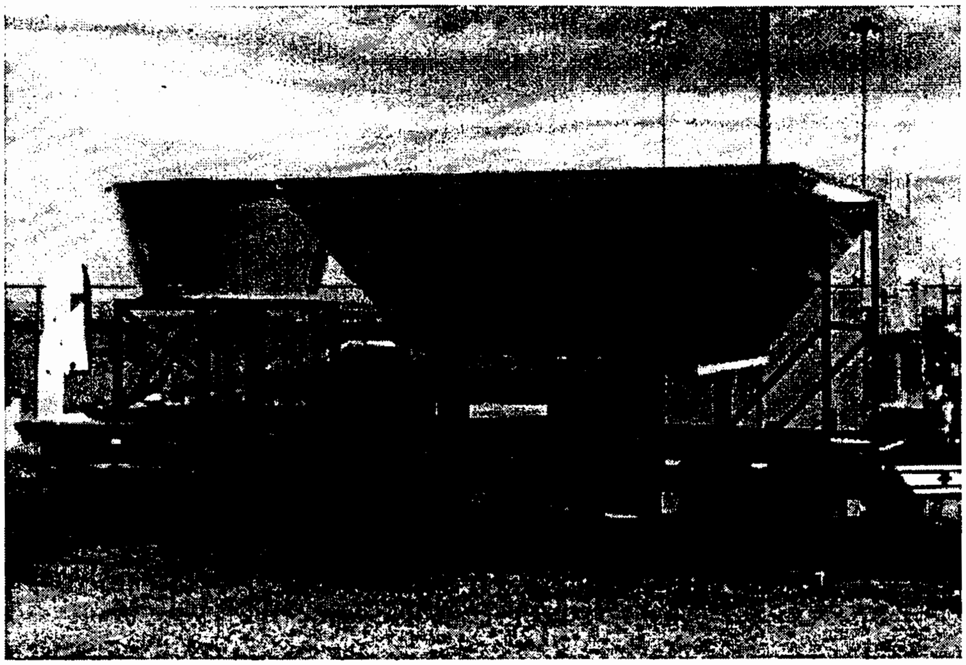

Figure 1. Remote sensors mounted on flatbed trailer. From left to right: Ceilometer, sodar, and radar.

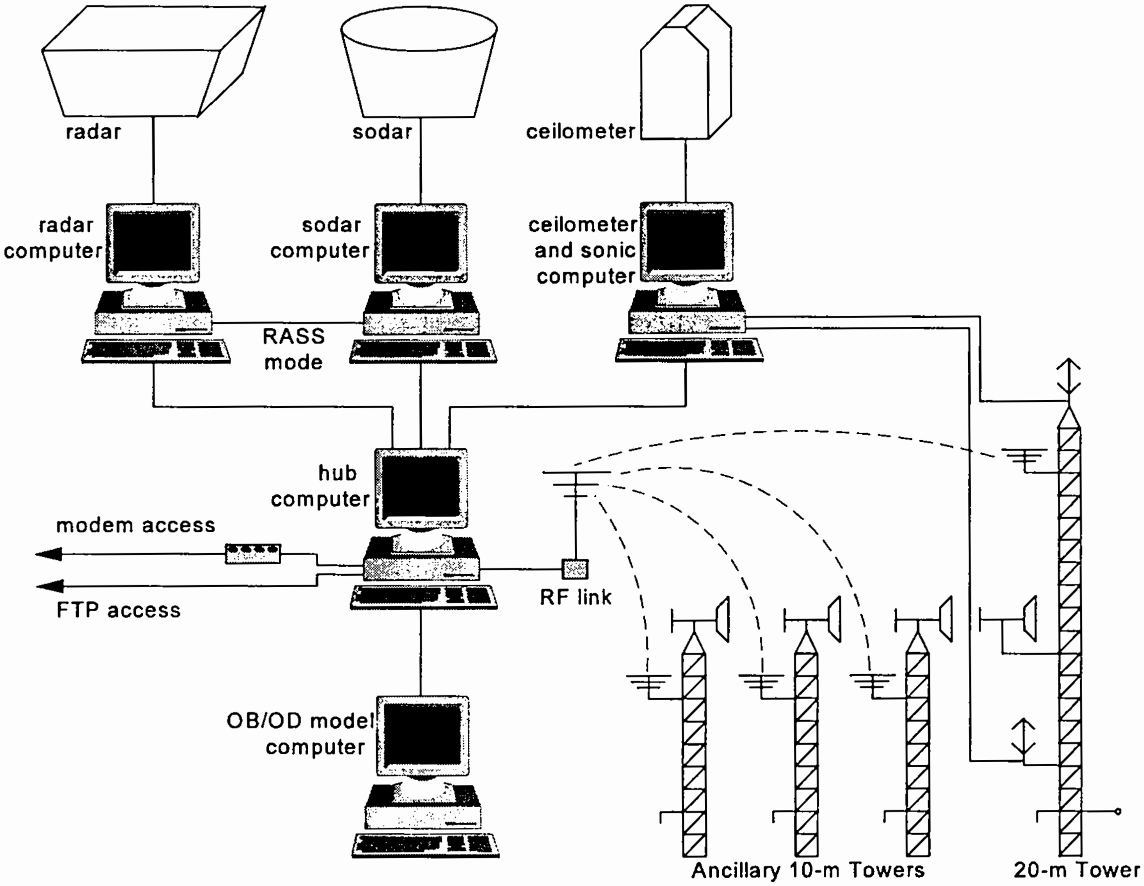

Figure 2. Schematic of mobile meteorological monitoring system.

TECHNICAL REPORT DATA

1. REPORT NO.
EPA/600/A-97/027

2.

3.RE

4. TITLE AND SUBTITLE
A Mobile Meteorological Monitoring System for Use in Open Burning and Open Detonation Activities

5.REPORT DATE

6.PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
[1]CRESCENTI, Gennaro H., and [2]TEMPLEMAN, Brian D.

8.PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

[1]Same as Block 12

[2]Cooperative Institute for Research in Environmental Sciences
University of Colorado
Boulder, CO 80309

10.PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS

National Exposure Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

13.TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
EPA/600/9

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A mobile meteorological monitoring system of *in situ* and remote sensors has been designed and constructed to characterize the atmospheric boundary layer from the surface up to 2 to 3 km at facilities which conduct open burning (OB) and open detonation (OD) of surplus (demilitarized) military munitions. Surface layer measurements include horizontal wind speed and direction, air temperature, relative humidity, net radiation, barometric pressure, precipitation, and turbulence. Vertical wind profiles are acquired by a Doppler sodar and a radar wind profiler. The sodar and radar work in unison as a radio acoustic sounding system (RASS) to acquire virtual air temperature profiles. A ceilometer has been included for estimation of the mixed layer height. These remote sensors are mounted on a flat bed trailer which allows easy transport from one OB/OD facility to another. All of the computers used for data acquisition are networked together into a primary computer. The meteorological data are used by an OB/OD for predicting transport and dispersion of emissions released into the atmosphere.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b.IDENTIFIERS/ OPEN ENDED TERMS	c.COSATI

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS *(This Report)*
UNCLASSIFIED

20. SECURITY CLASS *(This Page)*
UNCLASSIFIED

21.NO. OF PAGES

22. PRICE