ARMY RESEARCH LABORATORY

Campbell Systems Sampling Mean Conditions in an Urban Environment at White Sands Missile Range (WSMR), NM

by Manuel D. Bustillos*, Gail T. Vaucher, Sean D'Arcy, Ronald M. Cionco, Robert Dumais, and Robert Brice

ARL-TR-3926 **September 2006**

Army Research Laboratory

White Sands Missile Range, NM 88002-5501

ARL-TR-3926 **September 2006**

Campbell Systems Sampling Mean Conditions in an Urban Environment at White Sands Missile Range (WSMR), NM

Manuel D. Bustillos*, Gail T. Vaucher, Sean D'Arcy,
Ronald M. Cionco, Robert Dumais, and Robert Brice
Computational and Information Sciences Directorate

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* September 2006	**2. REPORT TYPE** Final	**3. DATES COVERED (From - To)**
4. TITLE AND SUBTITLE Campbell Systems Sampling Mean Conditions in an Urban Environment at White Sands Missile Range (WSMR), NM		**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Manuel D. Bustillos*, Gail T. Vaucher, Sean D'Arcy, Ronald M. Cionco, Robert Dumais, and Robert Brice		**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Computational and Information Sciences Directorate Battlefield Environment Division (ATTN: AMSRD-ARL-CI-EE) White Sands Missile Range, NM 88002-5501		**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-TR-3926
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory 2800 Powder Mill Road Adelphi, MD 20783-1197		**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)** ARL-TR-3926

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report provides documentation on Campbell systems, which are used to sample mean atmospheric conditions in an urban environment. This report includes mean condition measurements used in an U.S. Army Research Laboratory (ARL) Urban Study conducted at White Sands Missile Range, NM, in 2005. Secondly, the report summarizes the Army relevance for the WSMR 2003/2005 Urban Field Study. It describes an overview of the actual WSMR 2004/2005 Urban Study; the elements of the Campbell's contributions, sensor details, and sensor descriptions; measurement rates; lessons learned from the WSMR 2005 Urban Study; and a conclusion. The report also describes a valuable piece of data acquisition for modeling that still leaves much room for improvement. NOTE: The Campbell instrumentation setup is mostly an off-the-shelf unit that collects data using two groups of instruments.

15. SUBJECT TERMS

Campbell, Urban, Mean Conditions Study, Environmental Study, Airflow

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Manuel D. Bustillos
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	SAR	22	**19b. TELEPHONE NUMBER** (*Include area code*) 505-678-2987

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

List of Tables

Acknowledgments

Appreciation is extended to the U.S. Army Research Laboratory, Battlefield Environment Division's Characterization and Analysis Team (CAAT) and Micro Modeling Team (MMT) at White Sands Missile Range (WMSR), NM. The participating Teams and members included Jimmy Yarbrough, David Quintis, Doyle Elliott (CAAT). Also thanks go to Dr. Don Hoock, Linda Duchow, Felipe Chavez, Mike Mason, Rick Hanson, Felicia Chamberlain, Joseph Trammel, SGT Robert Brice, and the Military Detail support.

INTENTIONALLY LEFT BLANK.

Summary

The purpose of this report is to provide documentation on sampling mean conditions in an urban environment with Campbell systems, which is a mostly off-the-shelf instrumentation setup unit that collects data using two methods of collection. This report includes a summary of the U.S. Army relevance for the White Sands Missile Range (WSMR) 2003/2005 Urban (Field) Study. It also describes an overview of the actual WSMR 2003/2005 Urban Study; the elements of the Campbell's contribution, sensor details, and descriptions; lessons learned from WSMR 2005 Urban Study; and a conclusion. Overall, the report describes a valuable piece of data acquisition for modeling that still leaves much room for improvement.

The purpose of the "WSMR 2005 Urban Study: Airflow and Stability Around a Single Building" was to investigate airflow behavior around and above a single building, as well as to examine the surface layer stability transition patterns in an urban environment. The air movement was tracked using Campbell system instrumentation mounted on 10 m towers in parallel with R.M. Young ultrasonic anemometers. A single ultrasonic anemometer and flags tied to 2 m post fencing on the northeast and southeast side of the U.S. Army Research Laboratory building visually mapped the horizontal side eddies.

Data results from such studies contribute to the decision aids needed to model and create experimentation systems of chemical and biological agents in complex/urban terrains. Application of this information is intended to provide knowledge for the new transformation needed by the Department of Defense and the U.S Army in order to deal with the threat of chemical and biological weapons, as well as address the diversity of interest by the U.S. Department of Homeland Security by giving analyst assistance to help emergency, law enforcement, and first response personnel to train for potential terrorist attacks.

1. Introduction

"As the Department of Defense (DoD) continues its transformation to meet 21st century threats such as terrorism…Defense Secretary Donald H. Rumsfeld and Pentagon officials emphasized to America that transforming DoD training is the key to preparing for 21st century security threats." This statement is part of the ongoing war against global terrorism and positions the U.S. military transformation efforts toward an imperative goal[1].

Such statements insist on quality-assured meteorological, airflow, and turbulence datasets in order to establish confidence in the outdoor dispersion models used to simulate the dispersal of potentially toxic agents in an urban environment. The U.S. Army Research Laboratory (ARL) Urban Studies address airflow and turbulence over, around, and about a building; this information can be of great interest to today's U.S. Army and others whose battleground involves terrorism in an urban setting.

The data results from urban field experiments, like the "White Sands Missile Range (WSMR) 2005 Urban Study: Airflow Stability Around A Single Building," contribute to the decision aids needed to model and create experimentation systems of chemical and biological agents in complex/urban terrains. Such data can be used to better understand the behavior of turbulent airflow and eddies, making it possible to identify the atmospheric dispersion of potentially toxic agents in an early mission urban setting, and can help to improve, refine, and verify computer models that simulate the atmospheric transport of contaminants in urban areas. Application of this information is intended to provide knowledge for the new transformation needed by DoD and the U.S Army to deal with the threat of chemical and biological weapons, as well as to address the diversity of interest in the U. S. Department of Homeland Security by giving analyst assistance to help emergency, law enforcement, and first response personnel to train for potential terrorist attacks.

This technical report focuses on the second of two ARL WSMR Urban Studies, and it documents Campbell systems sample mean condition measurements in the urban environment. Section 2 describes the WSMR 2005 Urban Study. Section 3 details the Campbell instrumentation setup. Section 4 includes sensor details and descriptions, such as sensor selections and instruments specifications, including some insights into how to prepare for a scientific field experiment using Micrologger BASIC programming (i.e., data processing and analysis routines; program generation; editing; data retrieval; and real time monitoring). Section 5 goes over the lessons learned and section 6 provides the conclusion.

[1]Gilmore, G.J. News Articles Defenselink, U.S. Department of Defense American Forces Press Service. http://www.defenselink.mil/news/Aug2003/n08142003_200308144.html (accessed June 2006), p 1 of 4.

2. The WSMR 2005 Urban Study

In 2003, ARL's Measurements, Instrumentation and Analysis Team (MIAT) joined the Small, Scale Processes Team (SSPT) to conduct a series of field studies measuring airflow and stability about a single building in WSMR, NM. The 2004 Urban Study (Mr. Cionco, Ms. Vaucher, and Mr. Yee) mainly focused on the effects of a building on mean flow conditions. The purpose of the 2005 Urban Study (Ms. Vaucher, Mr. Cionco, Mr. Bustillos, Mr. D'Arcy, Mr. Dumais, SGT. Brice, and Military Detail support) was to serve as a final study addressing turbulent flow and eddy behavior about the same building used in previous studies. The study investigated airflow behavior around and above the building and examined the surface layer stability transition patterns in an urban environment.

The WSMR 2005 Urban Study began with a series of team decisions. First, a test plan was formulized to meet the requirements. The test plan covered the mission objectives; the location of sensors and equipment; and a detailed full test method that included a Lab Test, a Pre-Test Calibration, Test Execution, a Post Test Calibration, and an Internal Project Review by the team.

To characterize the day/night urban setting, there are two steps in the field execution:

1. The preparation of instruments for outdoor measuring patterns in the atmosphere around one building at ARL in WSMR, NM
2. Field study of execution

With the study execution, two scientific objectives were addressed: the first was sensing the thermodynamic patterns in an urban environment and the second was placing two groups of instruments for optimal characterizing of the two scientific objectives.

This report gives the details of the experimental layout used to accomplish the WMSR 2005 Urban Study. It identifies the teams' preparation for the joint-effort field experiment, as well as the equipment, areas, and various meteorological measurement instruments used on the four 10 m towers and the single 5 m tower, which were placed on top of the building. The air movement was tracked using Campbell instrumentation mounted on the 10 m towers, in parallel, with ultrasonic anemometers. A single ultrasonic anemometer and flags tied on 2 m post fencing on each side of the ARL building visually mapped the horizontal side eddies.

The data analysis and resulting conclusions based on the airflow and turbulence data studied in the WSMR 2005 Urban Study will be presented in other technical reports. For more information see technical report ARL-TR-3851[2].

---

[2]Vaucher, G. *White Sands Missile Range Urban Study: Flow and Stability Around a Single Building, Part 1: Background and Overview*; ARL-TR-3851; U.S. Army Research Laboratory: White Sands Missile Range, NM, July 2006.

3. Campbell System Instrumentation

The Campbell systems were successful in identifying the “thermodynamic features of patterns around the single building creating its own heat island studied in the rural or urban cycle of stability.” Also, the systems provided the mean wind flow parameterization.

The WSMR Urban Study used mostly an off-the-shelf design that featured two methods of data collection technology: wireless and hardwired. Such systems have been used successfully in previous studies.

The Campbell instrumentation setup was hardwired, and the Campbell Scientific systems were programmed for five sensors and were supplemented with other peripherals. Each Campbell Logger unit successfully sampled and measured the mean conditions for the WMSR 2005 URBAN Study. The data microloggers were self-contained and were connected to a set of the five sensors, measuring six variables: pressure, temperature, relative humidity (RH), wind speed, wind direction, and solar radiation. The Campbell Logger units successfully stored the programs and data acquired during the Pre-Study Calibration the WSMR 2005 URBAN Study and Post Study Calibration. Finally, the Campbell units performed measurement downloads for processing, displaying, and plotting data for further study and analysis.

The Pre-Test and experiment equipment utilized a Toshiba laptop computer, a Tripod Sensor Mast, and four 10 m towers.

4. Documenting Details/Instruments Descriptions

4.1 Sensor Selection

4.1.1 CR23X Micrologger (figure 1)

- The unit has an input and output connections that communicate with power sensors and peripherals.
- This micro unit has an alphanumeric display and keyboard.
- For programming and data downloads, the unit has a RS-232 port.

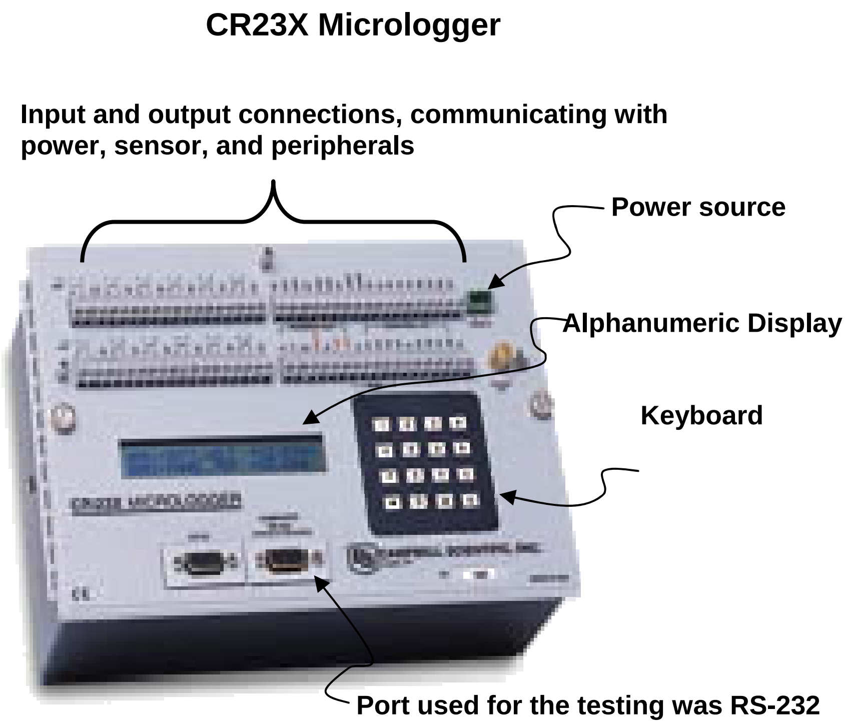


Figure 1. The CR23X Micrologger.

4.1.2 PTB101 Barometer (figure 2)

- Measures barometric pressure from 600 to 1060 mbar
- Accuracy: ±0.5 mbar at 20 °C
- Temperature range: –40 to 60 °C

PTB101B Barometer

✓ Measures barometric pressure form 600 to 1060 mbar
✓ Accuracy ±0.5 mbar at 20 °C
✓ Temperature range –40 to 60 °C

Figure 2. The PTB101 barometer.

4.1.3 Kipp and Zonen CM# Pyranometer (figure 3)

- Measures solar radiation at 2.5 m
- Spectral response waveband: 305 to 2800 µm
- Maximum irradiance: 2000 W/m^2
- Signal output: 0 to 50 mV

Kipp and Zonen CM3 Pyranometer

✓Measures solar radiation at 2.5 m
✓Spectral response wave band 305 to 2800 nm
✓Maximum irradiance 2000 W/m^2
✓Signal output 0 to 50 mV

Figure 3. The Kipp and Zonen CM# pyranometer.

4.1.4 Temperature Probe T-107 (figure 4)

- Measures temperature from –35 to 50 °C at 10 m above ground level (AGL)
- It is encapsulated in cylindrical aluminum housing.

Temperature Probe T-107

✓ Measures temperature from –35 to 50 °C at 10 m above ground level (ARL)

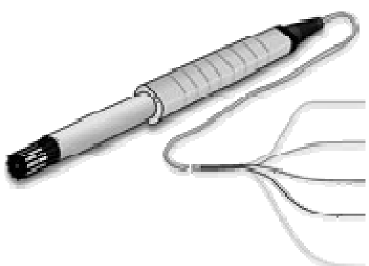
✓ The probe is encapsulated in a cylindrical aluminum housing.

Figure 4. The temperature probe T-107.

4.1.5 HMP45C-L Vaisala Temperature/RH Probe (figure 5)

- Measures temperature and RH at 2.5 m
- Accuracy: ±2% over 10% to 90% RH; ±3% over 90% to 100% RH
- Operating temperatures range –40 to 60 °C

HMP45C-L Vaisala Temperature / RH Probe



- ✓ Measures temperature and RH a 2.5 m
- ✓ Accuracy: ±2% over 10% to 90% RH; ±3% over 90% to 100% RH
- ✓ Operating temperature range –40 to 60 °C

Figure 5. The HMP45C-L Vaisala temperature/RH probe.

4.1.6 05305-L R.M. Young Wind Monitor (figure 6)

- Measures wind speed at 5 m
- Range: 0–90 mph (0–40m/s)
- Starting threshold: 0.9 mph (0.4 m/s)
- Measures wind direction
- Range: 0°–360° mechanical, 355° electrical (5° open)
- Accuracy: ±3°

05305-L R.M. Young Wind Monitor

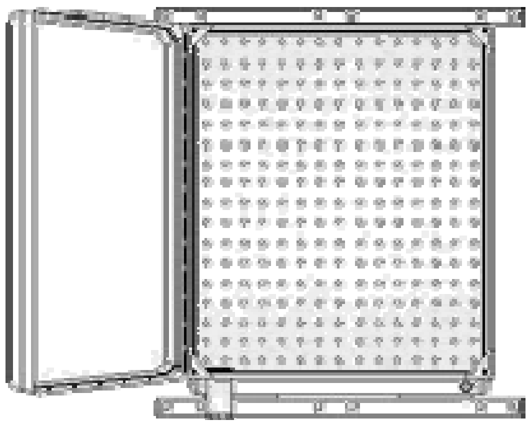
- ✓ Measures wind speed at 5 m
- ✓ Range: 0-90 mph (0-40 m/s)
- ✓ Starting threshold : 0.9 mph (0.4 m/s)
- ✓ Measures wind direction
- ✓ Range: 0-360° Mech., 355° Elec. (5° Open)
- ✓ Accuracy: ±30°

Figure 6. The 05305-L R.M. Young wind monitor.

4.1.7 ENC 16/18 Enclosure Series Scientific Box (figure 7)

- Mounting Bracket: Double and Triple, notch for UT-10 or UT-20 towers
- Internal dimensions: 16"×18"× 9"
- External dimensions: 21.75"×20"×11"

ENC 16/18 Enclosure Series Weather Resistant Scientific Box



✓ Provides a fiberglass-reinforced polyester enclosure

✓ Houses the data logger and its peripherals; is non-corrosive, white ultraviolet (UV)-stabilized; and reflects solar radiation, reducing the temperature inside.

✓ Internal dimensions 16"x18"x 9"

✓ External dimensions 21.75"x20"x11"

✓ The enclosure has a 1.25" diameter port for cable entry

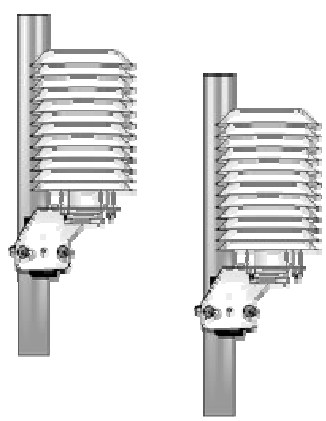
✓ Mounting bracket double and triple, notch for UT-10 or UT-30 Towers

Figure 7. The ENC 16/18 Enclosure Series scientific box.

4.1.8 41002 12 Plate Grill Radiation Shields (figure 8)

- Height: 8.0" (20.3 cm)
- Diameter: 4.7" (11.9 cm)

41002 12 Plate Grill Radiation Shields



✓ Height 8.0" (20.3 cm)
✓ Diameter 4.7" (11.9 cm)

Figure 8. The 41002 12 plate grill radiation shields.

4.2 Field Study Preparation

For WSMR 2005 Urban Study, the Campbell system sampled mean condition measurements for the field study preparations. Figure 9 shows the mean condition side by side comparison setup and figure 10 shows the Campbell loggers being checked for data relevance during calibration. During the preparation, various instruments and the data collection system timestamps were calibrated. There were several stages to the preparation:

Figure 9. Campbell system calibration side by side comparison.

Figure 10. Campbell data logger during calibration.

1. The 10 m towers were laid out to identify the required heights, fasteners, grounding cables, cable tiedowns, data cables, tower cross-arms, and instrument placing.
2. The instrument calibrations for the R.M. Young wind monitor were made using an R.M. Young 1800 rpm calibration instrument.
3. A wind tunnel simulation was arranged with a Toro air blower*.

Another important part of the experiment was the preparation of the timestamp verification, which was established using the National Institute of Standards and Technology's[3] (NIST) time standard. Table 1 describes the success of the time stamps throughout the entire experiment preparation.

---

*Ultra 225 Model 51598.

[3]The National Institute of Standards and Technology Home Page. http://nist.time.gov/about.html (accessed June 2006).

Table 1. The success of the time stamps throughout the entire experiment preparation.

Station	Start	Stop	Duration (Final – Initial)	Data Logger/NIST Difference at Stop Time[a] (s)
Computer	Jan 27, 15:24:00	Feb 15, 07:39:11	+18 d, 16 h, 15 min, 11 s	+0:01
1622_N	Jan 27, 15:24:00	Feb 15, 07:39:11	+18 d, 16 h, 15 min, 10 s	–0:01
1622_NE	Jan 27, 15:24:00	Feb 15, 07:32:11	+18 d, 16 h ,08 min, 12 s	+0:01
1622_S	Jan 27, 15:24:00	Feb 15, 07:50:11	+18 d, 16 h, 26 min, 12 s	+0:01
1622_SW	Jan 27, 15:24:00	Feb 15, 07:36:11	+18 d, 16 h ,12 min, 12 s	+0:01

[a]Difference = (NIST time standard) – (Campbell data logger)

5. Lessons Learned

Pre-Tests are thought to be very time consuming and are often seen as not needed. However, our experience with the Pre-Test for the WSMR 2005 Urban Study proved just the opposite. In this study, we found the Pre-Test to be an excellent calibrator for the final success of the experiment. It proved to be a good method of side-by-side comparison of instruments, quality timestamps, pre-cost analysis, and good data quality analysis. Also, the pretest identified three ailing ultrasonics before execution of the actual field study. The team acknowledged it as an opportunity to validate our assumptions and challenges our confidence.

For future field experiments, we recommend that ARL use our team's methods and lessons learned.

6. Conclusions

In summary, this report provides and documents Campbell systems sampling mean condition in an urban environment for future ARL urban studies. This report includes information on sensor selection; measurement rates; and analog and digital inputs and outputs, as well as provides some insights into how to prepare future scientific field experiments. The report also provides documentation of the instrument contributions and describes a valuable piece of data acquisition for modeling that still has much room for improvement. One improvement is for the Campbell data collection design and construction to be wireless. NOTE: The Campbell instrumentation setup was mostly an off-the-shelf unit and the data was collected by the field researcher walking to each tower where the data-logger is stationed and collecting the data via laptop download. For future field experiments, we would recommend that ARL uses our team's methods and lessons learned. For these reasons, we have documented our findings in this report.

Acronyms

AGL	above ground level
ARL	U.S. Army Research Laboratory
CAAT	Characterization and Analysis Team
MIAT	Measurements, Instrumentation and Analysis Team
MMT	Micro Modeling Team
SSPT	Small, Scale Processes Team
WSMR	White Sands Missile Range

Distribution List

US ARMY RESEARCH LAB ATTN IMNE ALC IMS MAIL & RECORDS MGMT ADELPHI MD 20783-1197	1
DEFENSE TECHNICAL INFO CTR ATTN DTIC OA MS CORA SANTOS 8725 JOHN J KINGMAN RD STE 0944 FORT BELVOIR VA 22060-6218	1 ELEC
US ARMY RESEARCH LAB AMSRD ARL CI OK TL TECHL LIB 2800 POWDER MILL ROAD ADELPHI MD 20783-1197	2
US ARMY RESEARCH LAB AMSRD CI OK TP TECHL LIB APG MD 21005	2
US ARMY RESEARCH LAB AMSRD ARL CI EE	
ATTN M. BUSTILLOS	7
G VAUCHER	1
R CIONCO	1
WSMR NM 88002-5501	
TOTAL	15 (14 hard copies + 1 electronic)

INTENTIONALLY LEFT BLANK.