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ASSESSMENT AND COMPUTERIZED MODELING OF THE ENVIRONMENTAL DEPOSITION OF MILITARY SMOKES

ANALYSIS OF METEOROLOGICAL DATA FROM THE AMADEUS SMOKE DISPERSION EXPERIMENTS

prepared by

D. F. Brown and W. E. Dunn
Department of Mechanical and Industrial Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801
217-333-3832

and

A. J. Policastro
Environmental Impact and Information Sciences Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
708-972-3235

June, 1990

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, MD 21702-5012

Contract No. 90PP0819

Contracting Officer's Representative: Major John Young
Health Effects Research Division
U. S. ARMY BIOMEDICAL RESEARCH AND DEVELOPMENT LABORATORY
Fort Detrick, Frederick, MD 21702-5010

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION University of Illinois at Urbana-Champaign and Argonne National Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439 University of Illinois, 1206 W. Green Street, Urbana, IL 61801	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION U.S. Army Medical Research and Development Command 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 90PP0819
8c. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, Maryland 21701-5012	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62720A PROJECT NO. 3E1-62720A835 TASK NO. CA WORK UNIT ACCESSION NO. 291

11. TITLE (Include Security Classification)

(U) Assessment and Computerized Modeling of the Environmental Deposition of Military Smokes

12. PERSONAL AUTHOR(S)

D. F. Brown, W. E. Dunn and A. J. Policastro

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 4/1/90 TO 6/30/90	June 1990	138

16. SUPPLEMENTARY NOTATION

Subtitle: Analysis of Meteorological Data from the AMADEUS Smoke Dispersion Experiments

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
04	01	
07	03	

18. SUBJECT TERMS (Continue on reverse if neccessary and identify by block number)

RA 3, smoke, screening smoke, obscuring smoke, hexachloroethane, gas chromatography

19. ABSTRACT (Continue on reverse if neccessary and identify by block number)

This report summarizes the meteorological data collected as part of the AMADEUS dispersion experiments. In addition, a preliminary analysis of these data was carried out. Averages of the surface-station and micrometeorological measurements were computed for each of 12 smoke release periods. Also, the stability of the atmosphere during these tests was characterized by analyzing (i) the standard deviation of the horizontal wind direction, (ii) the bulk Richardson number, (iii) the vertical profiles of wind and temperature, and (iv) direct measurements of the vertical heat and momentum fluxes. For four of the five daytime releases, the height of the boundary layer was determined from instrumented balloon soundings.

The results show that the meteorological data are complete and consistent, both internally and with other studies of the atmospheric boundary layer. The daytime convective conditions reveal a high degree of coherency, whereas the nighttime stable conditions are more spatially heterogeneous and less coherent. The stable boundary layer is generally less well understood than is the convective boundary layer, especially in a complex terrain setting. The data appear to offer significant potential for improving the state of dispersion modeling in this important area.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Mary Frances Bostian	22b. TELEPHONE (Include Area Code) 301-663-7325 22c. OFFICE SYMBOL SGRD-RMI-S

DD FORM 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

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FOREWORD

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W. E Dunn July 5, 1990

PI Signature Date

EXECUTIVE SUMMARY

In the Fall of 1987, a team of researchers from the University of Illinois and Argonne National Laboratory undertook a series of smoke dispersion trials at a complex terrain site in Northern California as part of a larger program to develop an improved model for smoke dispersion. These field trials were carried out in cooperation with researchers from several organizations working under contract to the US Army Atmospheric Sciences Laboratory at White Sands Missile Range in New Mexico. These field studies are known as the AMADEUS Dispersion Experiments.

The atmospheric conditions prevailing during each of the smoke and tracer release periods were determined as follows.

1. An array of 14 surface stations (instrumented at a height of 10 m) was used to map the horizontal variation of the wind field over the complex terrain site.

2. A micrometeorological tower was used to determine vertical profiles of wind and temperature to a height 30 m and to provide indirect measures of atmospheric stability through fluctuations in the wind velocity and temperature.

3. Two sonic anemometers were used to directly measure the vertical momentum and heat flux through the atmospheric boundary layer and thus provide additional data by which to characterize atmospheric stability.

4. Instrumented balloons were used to provide wind and temperature profiles to a height of several kilometers and thus allow the thickness of the atmospheric boundary layer to be determined.

5. A mini-sodar which employs reflected sound waves was used to characterize the atmospheric boundary layer to a height of roughly 300 m.

This report summarizes our effort to organize the large amount of meteorological data thus generated into a form which is suitable for validating and improving smoke dispersion models. In addition, a preliminary analysis of the meteorological data was carried out. Averages of the surface-station and micrometeorological measurements were computed for each of the smoke-release periods. Also, the stability of the atmosphere was characterized by analyzing (i) the standard deviation of the horizontal wind direction, (ii) the bulk Richardson number, (iii) the vertical profiles of wind and temperature, and (iv) direct measurements of the vertical heat and momentum fluxes.

For four of the five daytime releases, the height of the boundary layer was determined from the instrumented balloon soundings.

The results show that the meteorological data are complete and consistent, both internally and with other studies of the atmospheric boundary layer. The daytime convective conditions reveal a high degree of coherency, whereas the nighttime stable conditions are more spatially heterogeneous and less coherent. The stable boundary layer is generally less well understood than is the convective boundary layer, especially in a complex terrain setting. These data appear to offer significant potential for improving the state of dispersion modeling in this important area.

ACKNOWLEDGEMENT

We wish to acknowledge the contribution of the many organizations which participated in the AMADEUS dispersion experiments. The success of this study is a tribute to the professionalism of all those who were involved.

The contribution of two of our colleagues at the University of Illinois is especially noteworthy. Dr. James C. Liljegren and Dr. George E. DeVaull were essential members of our field team and contributed much to the analysis and understanding of the data. Also significant is the effort of Mr. Daniel Maloney who assisted in reducing the surface-station data.

We also wish to thank Maj. John Young, Maj. David Parmer and Dr. Howard Bausum of the U. S. Army Biomedical Research and Development Laboratory for their important role in shaping the project. It is through their efforts that our involvement in the AMADEUS experiments was made possible. Moreover, their many helpful suggestions and insightful comments added enormously to the success of our effort.

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NOMENCLATURE

Symbol	Meaning
c_p	Specific heat of air
d_i	Deviation used in computing σ_θ; lies in the interval (-180°, +180°)
E	Turbulent kinetic energy measured by sonic anemometer
g	Acceleration of gravity
L	Monin-Obukov length scale
mod	Modulo function; a mod b returns the remainder of a divided by b
N	Number of valid individual measurements in an average
n	Frequency; also used as counting index in computing averages
Q_o	Vertical-velocity/temperature correlation measured by sonic anemometer
R	Ideal gas constant for air
Ri	Gradient Richardson number
Ri_B	Bulk Richardson number
S	Scalar-mean wind speed
s_i	An individual wind speed measurement which may be either a 1-s value or 1-min average
$S_{uu}(n)$	Single-sided power spectrum for u-velocity fluctuations
$S_{vv}(n)$	Single-sided power spectrum for v-velocity fluctuations
$S_{ww}(n)$	Single-sided power spectrum for w-velocity fluctuations
T	Mean temperature; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
T_{2m}	Mean temperature at a height of 2 m
T_{10m}	Mean temperature at a height of 10 m
ΔT	Temperature difference; for example, $T_{10m} - T_{2m}$
t	Time
U	Vector-mean wind speed; also the scalar mean of u
U_1	Scalar-mean of u_1
U_2	Scalar-mean of u_2
U_3	Scalar-mean of u_3
u	Component of wind velocity in the direction of the mean wind; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average

Symbol	Meaning
u_1	First Cartesian (horizontal) component of the wind velocity; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
u_2	Second Cartesian (horizontal) component of the wind velocity; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
u_3	Third Cartesian (vertical) component of the wind velocity; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
u_*	Friction velocity
V	Scalar mean of v; zero by definition
v	Component of wind velocity normal to the direction of the mean wind; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
W	Scalar mean of w
w	Vertical component of wind velocity; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
w_*	Convective velocity scale
z	Height above ground
z_i	Height of boundary layer; inversion height
z_o	Roughness height
z_u	Height at which wind speed or velocity is measured
z_{T1}, z_{T2}	Heights at which temperature is measured
ϕ	Inclination of wind velocity
κ	von Kármán's constant = 0.4
θ	Vector-mean wind direction; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
ρ	Density of air
$\bar{\rho}$	Average density across a layer
σ_u	Standard deviation of u
σ_v	Standard deviation of v

Symbol	Meaning
σ_w	Standard deviation of w
σ_T	Standard deviation of T
σ_θ	Standard deviation of horizontal wind direction; an "i" subscript denotes an individual measurement and may be either a 1-s value or 1-min average
$\sigma_{\theta,1\ min}$	Standard deviation of horizontal wind direction computed from 1-min averages of θ

1. INTRODUCTION

In the Fall of 1987, a team of researchers from the University of Illinois (UIUC) and Argonne National Laboratory (ANL) undertook a series of smoke dispersion trials at a complex terrain site (the Meadowbrook Site) in Northern California as part of a larger program to develop an improved model for smoke dispersion. This work was carried out under the sponsorship of the US Army Biomedical Research and Development Laboratory (USABRDL). In addition, these field trials were performed in cooperation with researchers from several organizations working under contract to the US Army Atmospheric Sciences Laboratory (ASL) located at White Sands Missile Range, New Mexico. The dispersion trials discussed herein actually represent only a small part of the total ASL effort which had as its major objective the validation and improvement of certain of the wind field models developed by ASL. This larger effort, known as Project WIND, involved four major field studies; the dispersion trials of interest here were carried out during the fourth such study. In the terminology of Project WIND then, the field studies described herein are known as the AMADEUS Dispersion Experiments carried out at the Meadowbrook Site during Phase IV of Project WIND.

The effort produced a large amount of valuable data on dispersion in complex terrain. Two sets of dispersion experiments were actually conducted. In addition to the 12 smoke trials of primary interest here, 11 tracer releases were also made. The tracer gas was sampled over a larger but more sparse grid than was the smoke. Also, the tracer gas was collected using bag samplers which give 5-min average values. The smoke, on the other hand, was collected using filter samplers operated over the full duration of the trial and was simultaneously sampled every second using an optical device. The tracer gas collectors were placed on the ground giving an effective sampling height of a few centimeters. The smoke concentration was measured at heights of 2 and 8 m using the filter samplers and at a single height of 2 m using the optical device. Depending on the trial, 30 to 40 locations were used for sampling the smoke.

Several different organizations, each with its own essential role to play, participated in the AMADEUS dispersion experiments. The major participants, in addition to the ASL and UIUC/ANL teams, included:

1. The Physical Sciences Laboratory of New Mexico State University who operated eight 10-m surface stations and provided additional support to the ASL coordinators.

2. Nowcasting of Chico, California, who operated two additional 10-m surface stations and provided weather forecasts to aid in the planning of the smoke and tracer releases.

3. The NOAA Atmospheric Research Laboratory of Idaho Falls, Idaho who operated (i) three 10-m surface stations and (ii) one 30-m micrometeorological instrument tower with additional wind speed and direction instruments at the 10-m and 30-m levels. Since the 30-m tower doubles as a 10-m and a 30-m surface station, the total number of surface stations operated by ARL is effectively five. In addition, the ARL team made the releases of the tracer gas, collected the tracer gas using the 5-min bag samples and carried out the chemical analysis of the collected gas.

4. Risø National Laboratory of Denmark who made aerial photographs of the smoke plume and also operated two sonic anemometers which directly measure the turbulent heat and momentum fluxes.

5. The US Forest Service which was responsible for coordinating the project with local governmental agencies and for video taping the smoke releases. The Forest Service also provided radios for intergroup communication and monitored all activities for potential fire hazard.

In addition, several other contractors provided support of various kinds.

A complex array of instruments was used to determine the atmospheric conditions during each dispersion trial as identified below.

1. Fourteen surface stations were used to map the horizontal variation of the surface winds over the complex terrain site. Thirteen of these stations were 10-m masts equipped with cup anemometers and direction vanes at the 10-m level. In addition, the 30-m tower identified in Item 2 below was instrumented with cup anemometers and direction vanes at the 10-m and 30-m levels, thus providing one additional 10-m surface wind measurement and a corresponding wind measurement at 30 m. Except for the 30-m tower, all of the surface stations include temperature measurements at the 10-m level, and eight of the these stations also provide temperature measurements at the 2-m level. Moreover, temperature measurements at the 2-m, 8-m and 30-m levels were used to augment the wind speed and direction data on the 30-m tower.

2. A micrometeorological tower was used to determine vertical profiles of wind and temperature to a height of 30 m and to provide indirect measures of atmospheric stability through the fluctuations in the wind velocity and temperature. This tower was instrumented with propellor anemometers (three independent directions) and temperature sensors at five levels: 2 m, 4 m, 8 m, 16 m and 30 m.

3. Two sonic anemometers were used to directly measure the vertical momentum and heat flux through the atmospheric boundary layer and thus provide additional data useful in characterizing atmospheric stability.

4. Instrumented balloons were used to provide wind and temperature profiles to a height of several kilometers and thus allow the thickness of the atmospheric boundary layer to be determined.

5. A mini-sodar which employs reflected sound waves was used to characterize the atmospheric boundary layer to a height of roughly 300 m.

The wealth of data generated by these state-of-the-art, research-grade instruments is quite large indeed, and the task of validating and archiving these data in a form that can be used for model improvement is equally large. The present report summarizes our work in this arena. It must be emphasized that this report represents a preliminary evaluation of the data; analysis has been carried out to the extent possible to assure the quality of the data overall and to identify areas of ambiguity and missing information. We designate this a "meteorological data archive report". As such, this report summarizes the procedures followed in converting the data from its raw form, as received by us from the various participating organizations (including ourselves), to the form we need for further evaluation. To assure the lasting value of the data, we summarize in a series of appendices various details of interest to researchers who will be using these data in the future. The organization we have chosen hopefully allows the report to thus serve a dual purpose. On the one hand, the report can be used to determine the overall scope and quality of the data from the information presented in Chapters 1–4. On the other hand, the report serves as our primary reference for the AMADEUS meteorological data base with much additional detail summarized in the Appendix.

In addition to the meteorological data described in this report, the following data are available as part of the AMADEUS data base.

1. Source data providing among other things the time history of the smoke release rate.

2. The time-averaged smoke concentration data collected at 2 m and 8 m using filter samplers.

3. The instantaneous smoke concentration data obtained using optical devices.

4. The tracer concentration measurements made using bag samplers.

5. More than 250 aerial photographs of the smoke plume taken during all but the nighttime smoke releases.

Future reports in this series will provide a more in-depth evaluation of the data and fully integrate the meteorological measurements with the results of the dispersion experiments.

2. OVERVIEW OF METEOROLOGICAL MEASUREMENTS

2.1 Test Site and Sampling Grid

The Meadowbrook site and sampling grid are shown in Fig. 2.1. This site, located approximately 20 miles east of Red Bluff, California in the foothills of the Sierra-Nevada Mountains, consists of a forked creek valley with surrounding slopes rising to a height of about 250 m above the valley floor. These slopes are covered with deciduous and coniferous trees reaching heights of 25 m, although the average height of the surrounding forest is about 8 to 10 m. The valley is formed by the joining of Plum Creek with Payne Creek in the relatively flat, clear floor area which is about 800 m across at its widest point. These two creeks flow down from the higher elevations east of the valley. The cleared area paralleling each of the two creeks narrows and eventually vanishes as elevation increases in each of the two branches of the creek fork.

The meteorology of the site is dominated by a density-driven, diurnal upslope-downslope flow pattern typical of mountain/valley topography. The elevation drops about 350 m over a distance of roughly 10 km from east to west. At night, colder, denser air flows down the mountain slopes into the valley; whereas, during the day, warmer, lighter air flows up the slopes from the valley floor. Mesoscale effects also influence the meteorology of the site. The Boise-Cascade Mountains to the west of the site block much of the moist air from the Pacific Ocean thus giving rise to an extremely dry local climate. As a result, daytime heating of the ground is intense with temperatures of 40 °C common in the valley floor. Nighttime cooling is equally strong with temperatures below 10 °C possible in the lower areas of the test site. The meteorology of the test area is well established, both through the nature of the terrain and through three previous large-scale wind-field studies carried out in Phases I–III of Project WIND.

To take advantage of these diurnal wind characteristics, two smoke release locations and associated sampling grids were established. One, known as the "unstable release point" is located at the west end of the valley floor as shown in Fig. 2.2. This release point was used for daytime experiments when upslope winds were anticipated. The "unstable" designation comes from the fact that a highly convective, unstable atmospheric boundary layer is expected under these conditions. The second location, known conversely as the "stable release point", lies in the upper reaches of the cleared area of the Plum Creek valley and is shown in Fig. 2.3. This location was used for the nighttime and early morning smoke releases when downslope winds and a stable atmospheric boundary layer were anticipated. The terms "stable" and

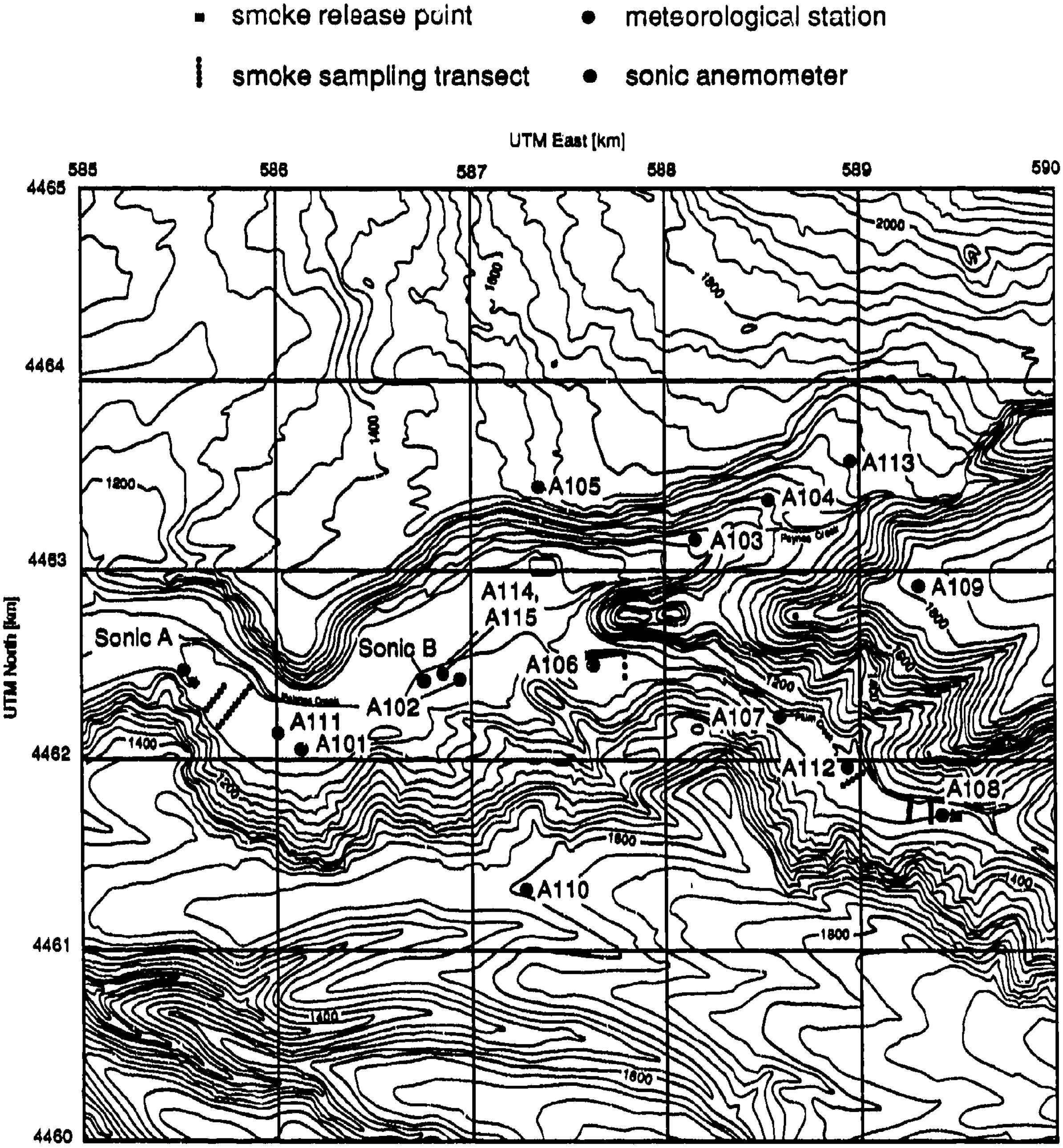
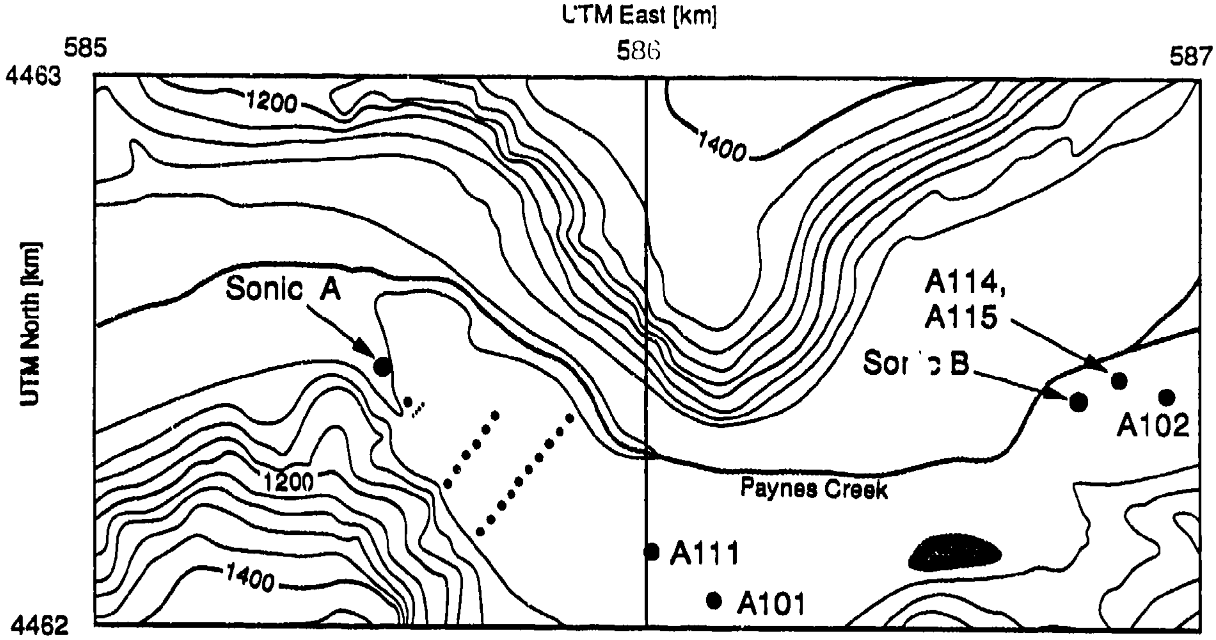
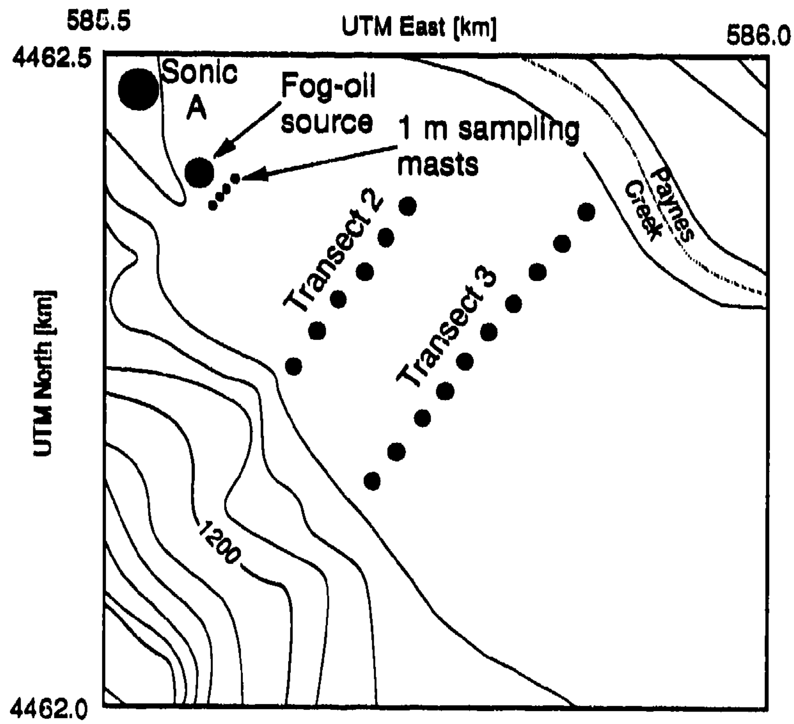


Figure 2.1 Topographical map of the Meadowbrook Site. Elevations are in feet above sea level with contour lines at increments of 40 feet. The horizontal scale is in Universal Transverse Mercator coordinates, with the grid marked in km. The topographical information is taken from the USGS map of Inskip Hill, California.



(a)



(b)

Figure 2.2 Close-up views of the "unstable" test area showing (a) locations of relevant meteorological instrument towers and (b) enlarged view of the sampling transects. The horizontal scale is in Universal Transverse Mercator coordinates, with the grid marked in km. Elevations are in feet above sea level with contour lines at increments of 40 feet The topographical information is taken from the USGS map of Inskip Hill, California.

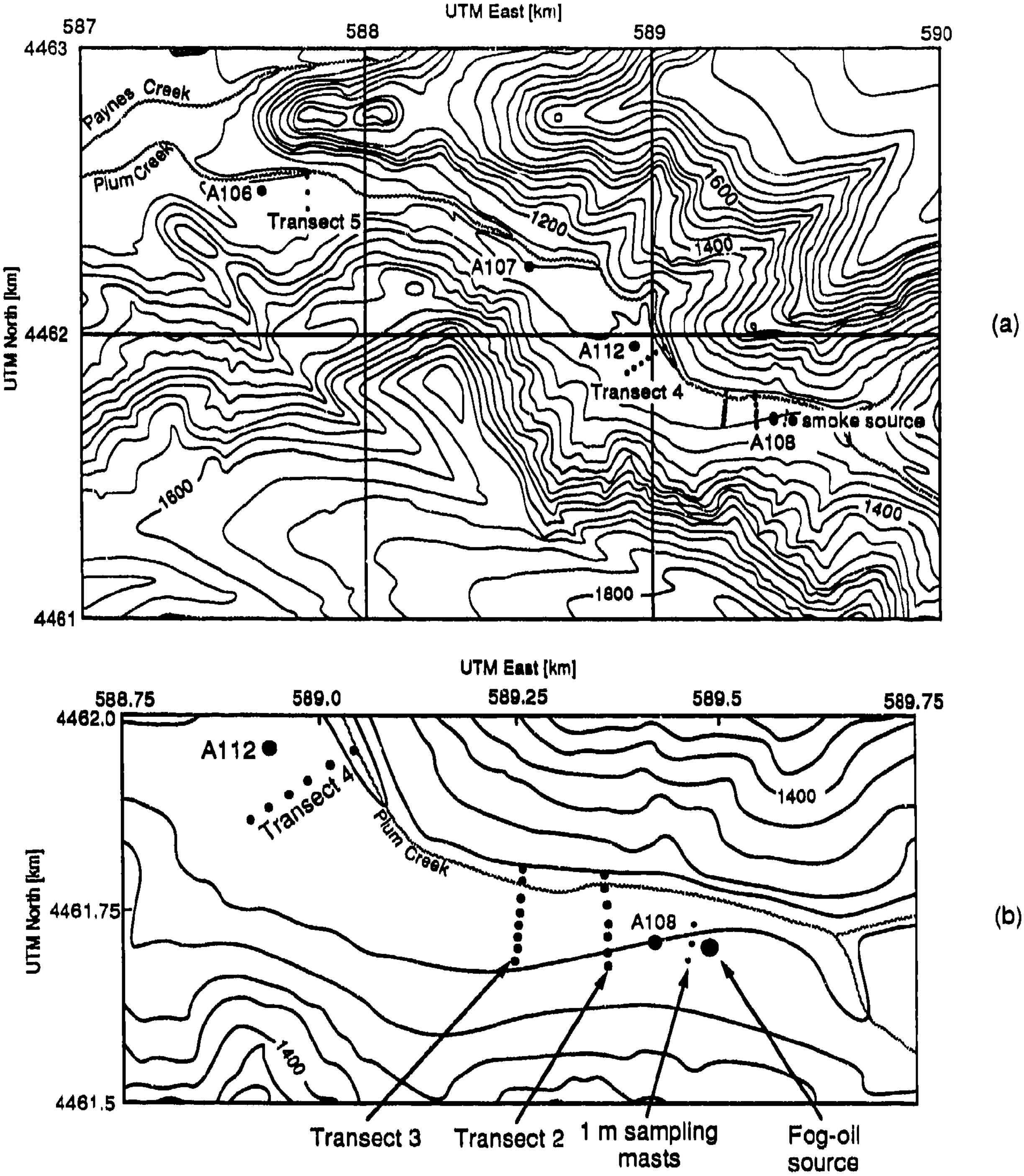


Figure 2.3 Close-up views of the stable test area showing (a) location of relevant meteorological instruments and (b) enlarged view of the sampling transects. The horizontal scale is in Universal Transverse Mercator coordinates, with the grid marked in km. Elevations are in feet above sea level with contour lines at increments of 40 feet. The topographical information is taken from the USGS map of Inskip Hill, California.

"unstable" must be used with caution, however, since their specific meanings become clouded in a complex terrain setting such as the Meadowbrook Site. Although somewhat imprecise, the terms do provide a simple, convenient and easily understood way to distinguish the two types of smoke releases. Moreover, the use of these labels has become so widespread in the AMADEUS literature that adopting a new terminology now would only serve to greatly confuse matters.

Near the unstable release point, the wind is predominantly from west to east. Samplers were operated along three transects to a distance of 250 m from the source as shown in Figs. 2.1 and 2.2. The high dilution rate of the smoke under highly convective conditions precluded measurement at greater distances. Because of the limited distance involved and the relatively flat terrain of the valley floor, little if any complex terrain effects on the dispersion were experienced.

Near the stable release point, the wind follows the gradient of the terrain quite well. The smoke dispersion was very sensitive to the local stability and surface roughness. Five rows of samplers spanning the width of the creek valley and covering a downwind distance to 2 km were used to sample the smoke released from this location as shown in Figs. 2.1 and 2.3. In a few of the tests, samplers located on the unstable-release-point grid were also operated to give a total sampling distance of more than 3 km.

In total, twelve smoke releases were made: five from the unstable release point and seven from the stable release point. The trials ranged from 12 to 67 minutes in duration with the majority of the releases lasting between 30 min and an hour. Seven of the trials (four during the day and three at night) were conducted under clear skies; the remaining five were carried out under partly cloudy conditions.

2.2 Surface Stations

An array of 14 surface stations was used to map the wind field over the complex terrain site. In its simplest form, a surface station measures the wind speed, (horizontal) wind direction and temperature at a height 10 m above the ground. A second temperature measurement at a height of 2 m can be added to determine the vertical temperature gradient (lapse rate) near the ground. Atmospheric stability can then be inferred from this information using the bulk Richardson number, although the accuracy of this procedure is a matter of some controversy in the literature. In some cases, these basic data are supplemented by additional measurements such as the soil temperature, the solar heat flux and the humidity.

During the AMADEUS Dispersion Experiments, 13 10-m surface stations equipped with cup anemometers and direction vanes were used. In addition, a 30-m micrometeorological instrument tower was located in the center of the valley floor as is more fully described later. Cup anemometers and direction vanes were mounted on this tower at the 10-m and 30-m levels. Thus, a total of 14 surface wind-field measurements were made at the 10-m level and one additional measurement was made at the 30-m level, giving 15 measurements in all.

The 30-m tower was also equipped with propellor anemometers (which measure the three components of the wind vector) at the 2-m, 4-m 8-m, 16-m and 30-m levels. The fact that two different types of instruments co-existed at the 30-m level allows readings from the two instruments to be compared. This comparison reveals that the cup anemometer reads consistently higher than the propellor anemometer by 10 to 20%. A similar comparison between the cup anemometer reading at the 10-m height and a value interpolated from the 8-m and 16-m propellor measurements yields the same conclusion. Based on the fact that the instruments were calibrated before use, the most likely explanation for this disparity lies in the response characteristics of the cup anemometer in a horizontally and vertically fluctuating wind field. Discussions with the scientists from the NOAA Atmospheric Research Laboratory who were responsible for operating these instruments confirmed the fact that their cup anemometers do, in fact, typically read higher than their propellor anemometers by the same percentage as was observed in this study.

Three different organizations were involved in gathering the surface-station data as follows:

1. Eight of the 15 stations, designated A101, A102 and A105-A110, were operated by the Physical Sciences Laboratory of New Mexico State University, Las Cruces, New Mexico. All eight of these stations were equipped with wind and temperature instruments at the 10-m level. The temperature difference between the 2-m and 10-m levels was also measured as was the soil temperature. These stations ran continuously (except for unscheduled down time) over the 17-day period during which the trials were conducted. One-minute averages were computed from 1-s samples by the data acquisition equipment in the field. These 1-min averages were saved and ultimately transferred to floppy disk.

2. Two of the 15 stations, designated A103 and A104, were operated by Nowcasting of Chico, California. Wind and temperature measurements were made at the 10-m level, but no auxiliary temperature measurements were made. Moreover, the temperature sensor on Station A103

exhibited a very slow response time as compared with the other surface-station sensors. These stations ran continuously for most of the testing period, although Station A103 did not operate during the first three smoke trials. One-minute averages were computed in the field from 1-s samples by the data acquisition equipment. These 1-min averages were saved and ultimately transferred to floppy disk.

3. Five of the 15 stations, designated A111 through A115, were operated by the NOAA Atmospheric Research Laboratory of Idaho Falls, Idaho. As previously noted, Stations A114 and A115 correspond to cup anemometers and direction vanes mounted at the 10-m and 30-m levels of the 30-m instrument tower. The temperature for Station A115 was taken as the value recorded by the micrometeorological sensor mounted at the 30-m level. Lacking a corresponding measurement at the 10-m level, we elected to use the actual value at the 8-m level rather than a value interpolated from the 8-m and 16-m data. These five stations were operated only during the smoke and tracer release periods. The data were sampled at 1-s intervals using a centralized data acquisition system. The 1-s data were transferred directly to nine-track magnetic tape, and 5-min averages were simultaneously produced for use by the Test Officer. We used the 1-s data on tape to generate 1-min averages of the same type available for the other surface stations.

2.3 Micrometeorological Measurements

A 30-m tower equipped with wind and temperature instruments at five levels (2 m, 4 m, 8 m, 16 m and 30 m) was operated by the NOAA Atmospheric Research Laboratory of Idaho Falls, Idaho as was previously noted. Propellor anemometers were used to measure all three components of the wind velocity, and the data were sampled remotely at a 1-Hz rate. In addition, laser anemometers were used to measure the bulk flow velocity through the valley at three levels.

The micrometeorological data serve two primary purposes: (a) to characterize the vertical variation in the mean wind speed, mean wind direction and mean temperature, and (b) to provide information on the turbulent components of the wind and temperature fields from which the structure of the atmospheric boundary layer may be inferred.

The micrometeorological tower operated only during specific periods encompassing the smoke and tracer releases.

In processing the data, it was discovered that there was an error in the wind direction at the 30-m level for several of the test periods. The worst of these are for (a) records starting at 21:00 on September 24 and ending at 02:40 on September 25 for which the disparity is 15-20°, (b) records starting at 02:15 on September 27 and ending at 07:50 on September 27 for which the disparity is 65-70° and (c) records starting at 09:40 on September 28 and ending at 13:45 on September 28 for which the disparity is 20°.

2.4 Surface Momentum and Heat Flux Measurements

Two sonic anemometers were operated by researchers from Risø National Laboratory in Denmark. These anemometers were located 7 m above the ground at the two locations indicated in Fig. 2.1. Owing to the rapid response time of these instruments, it is possible to directly measure the turbulent momentum and heat fluxes in the vertical direction, and thus provide direct information on atmospheric stability. In this study, velocity and temperature were sampled at the rate of 20 Hz.

The major limitation of the sonic-anemometer technique is that the measurement of fluxes, although direct, is made at a single point and thus does not necessarily provide a value representative of the entire area. The inhomogeneity of the terrain and meteorology only serves to exacerbate this problem. Moreover, the values often exhibit considerable variation with time as individual large-scale structures pass by the measuring point. To partially overcome the transient nature of the measurements, averages were computed over successive 10-min time periods. Only the 10-min averages were available for the analysis completed here.

Sonic Anemometer B, located near the micrometeorological instrument tower (Station A114), operated continuously, whereas Sonic Anemometer A, located near our unstable release point operated only when releases were made from that location.

2.5 Instrumented Balloon Soundings

Attention thus far has been focused on near-ground flow patterns and the stability of the atmospheric boundary layer. An equally important parameter for dispersion modeling is the height of the atmospheric boundary layer itself. In unstable conditions, the layer is normally capped by a strong inversion which lies near the ground at dawn and rises to an asymptotic height of as much as several kilometers over the course of the day due to solar heating of the ground. Bright sunny days with intense ground heating, such as are typical of the Meadowbrook Site, give rise to very convective boundary layers. Determining the height of the boundary layer under stable conditions is more problematic, since the state of knowledge of stable-boundary-layer physics is presently poor.

An instrumented balloon can be used to determine the vertical wind and temperature structure of the atmosphere to a height of several kilometers and, indeed, to heights of tens of kilometers. This device consists of a large, helium-filled balloon outfitted with a small instrument package which can measure pressure and temperature and radio this information to a ground-level tracking dish. The balloon is allowed to rise freely and its position is tracked by the ground station. Simultaneously, the instrument package telemeters backs the pressure and temperature data. Using the time history of the balloon position, the pressure data (from which height can be computed) and the temperature data, it is possible to determine vertical wind and temperature profiles.

Balloon soundings of this type can be used to determine an unstable boundary layer height using one of two methods. If a sounding is made during the day, the temperature inversion should be readily apparent and the height of the boundary layer immediately evident (at least in principle). Alternatively, the sounding can be made very early in the morning when the inversion is near the ground. To obtain the mixing height for any specific time of day, one combines the vertical profile of potential temperature thus determined with the local ground-level potential temperature measured directly at the time of interest. This method of determining mixing depth is routine in conventional meteorology and has been found to give estimates which are within 50% of the actual value. Lacking a valid sounding, one can estimate the mixing height from solar heating considerations (based on time of day, time of year and cloud cover information).

A valid sounding taken close to the time of the test is available for only one of our daytime releases. Morning soundings are available for three of the other four daytime releases. No upper air data is available for the one remaining daytime trial nor is any data available for the seven nighttime and early morning releases.

2.6 Mini-sodar Measurements

A mini-sodar device was operated periodically during the study by researchers from the Meteorological Section of the Environmental Research Division of Argonne National Laboratory. This device uses reflected sound waves to characterize the structure of the atmospheric boundary layer to a height of 300 m. These data are not in a useful form at the present time, and thus are not considered in this report.

3. METEOROLOGICAL DATA REDUCTION AND ANALYSIS

3.1 Surface-station Data

3.1.1 Measurement Locations

The layout of fixed instrumentation at the Meadowbrook Site was shown previously in Fig. 2.1. Table 3.1 gives the latitude and longitude of Stations A101–A110 and A114/115 as determined by ASL-contractor personnel. Also tabulated are the Universal Transverse Mercator (UTM) coordinates which we calculated from these values. The locations of Stations A111-A113 were supplied to us by NOAA personnel in UTM coordinates. The latitude and longitude coordinates were determined by the ASL contractor using a Loran-C electronic positioning system rather than by ground-based surveying. Although the readings are reported to a *resolution* of 1" in both latitude and longitude, which translates into an uncertainty of 24 m in latitude and 31 m in longitude at this site, the *accuracy* of the measurements is most probably between 2" and 10", depending on the quality and type of instrument actually used. Thus, the uncertainty in the horizontal positions determined from the reported latitude and longitude coordinates is expected to be between 50 and 250 m.

Due to the inaccuracies inherent in the Loran-C system, many of the surface station locations reported by the ASL contractor are substantially in error. This presents a serious problem, since the Meadowbrook site is characterized by complex terrain and very inhomogeneous meteorology. In an effort to resolve this problem, aerial photographs, ground-level photographs and UIUC/ANL survey information were analyzed to pinpoint the location of the stations.

Station A114/115 can be seen in aerial photographs, and its reported location appears to be correct. The UIUC/ANL team surveyed the unstable grid relative to Stations A114, A101 and A111. Using this survey information combined with the known location of Station A114/115, Stations A101 and A111 can be correctly located. Station A102 can also be recognized in an aerial photograph; it is about 40 m east of its reported location. The UIUC/ANL team used Stations A106, A108 and A112 as reference points in surveying the stable grid. Since Transects 4 and 5 are visible in the aerial photographs, these three stations can be correctly located from the UIUC survey. Using the elevation, temperature and wind direction data, we concluded that the reported location of Station A107 was grossly in error. We hypothesized that the station was, in fact, located in the middle of the Plum Creek valley. A personal communication with the ASL Project Leader (Mr. Ron Cionco) confirmed this suspicion and pin-

Table 3.1 Coordinates and elevations of meteorological surface stations as determined by ASL contractor personnel.

Station	Latitude	Longitude	UTM north	UTM east	Elevation [m]
A101	40°18'24"	121°59'11"	4462055	586104	321
A102	40°18'36"	121°58'37"	4462423	586903	323
A103	40°18'59"	121°57'43"	4463130	588173	370
A104	40°19'13"	121°57'21"	4463560	588690	449
A105	40°19'09"	121°58'18"	4463438	587350	465
A106	40°18'37"	121°58'06"	4462454	587632	332
A107	40°18'22"	121°57'29"	4461993	588502	355
A108	40°18'08"	121°56'54"	4461563	589324	390
A109	40°18'52"	121°56'55"	4462915	589301	554
A110	40°18'00"	121°58'21"	4461317	587279	491
A111	N/A	N/A	4462288	585924	321
A112	N/A	N/A	4462000	588909	369
A113	N/A	N/A	4463576	588955	457
A114/A115	40°18'37"	121°58'39"	4462454	586856	322

Table 3.2 Coordinates of meteorological surface stations as determined by the UIUC/ANL team. The difference column gives the horizontal distance between the location shown and that determined by ASL-contractor personnel as presented in Table 3.1.

Tower	UTM north	UTM east	Difference from reported [m]
A101	4462053	586125	21
A102	4462423	586942	39
A104	4463534	588369	322
A106	4462502	587632	48
A107	4462236	588501	243
A108	4461710	589422	177
A111	4462139	586010	123
A112	4461960	588937	49

pointed the location as the narrowest point of the Plum Creek valley. During this communication, it was also discovered that the reported location of Station A104 was substantially in error, and the correct location was established. Unfortunately, no such supplementary information was available by which to correctly locate Stations A103, A105, A109, A110 and A113. These stations are outside the sampling grids used in the smoke trials and thus knowing their precise location is fortunately less critical. Table 3.2 summarizes the revised locations and the errors for the eight stations for which corrected locations were obtained.

3.1.2 Data Manipulation

The data for Stations A101 - A110 were received at the University of Illinois in April, 1988 in the form of 103 IBM PC (360 kB) floppy disks contained in 10 separate boxes labeled by station number. The format and a sample of the raw data records is given in Appendix A. All data files were copied from floppy disk using an IBM PC/AT computer linked to a Sun 3/280 computer system via Ethernet. The data files were copied to a directory of the Sun Unix file system using PC Network File System. A listing of the raw data files by station is given in Appendix D. A UIUC-written utility called "dos2unix" was used to convert all data files from DOS text form to Unix text form so that further processing could be performed on the Sun computer system. The original DOS-image files were archived to tape. The data were processed using a combination of computer programs and manual editing to

(a) re-organize the data base into separate files each containing one full day's record for an individual station (A summary of the reduced data formats and file naming conventions is given in Appendix B.),

(b) eliminate redundant and/or extraneous information from the data records to reduce the overall size of the data files which must be handled,

(c) edit incomplete and errant data records to recover as much information as possible (A listing of bad data records appears in Appendix F.),

(d) remove repeated records present in the raw data files (A summary of repeated records eliminated from the data base is given in Appendix G.),

(e) fill in time periods absent from the original database with "missing data records" to simplify later processing and analysis (A summary of missing time periods is also given in Appendix G.), and

(f) convert missing data values to the standard string "-99999".

It should be noted that the format of the original data was completely preserved in the conversion process. Thus, all values are in the same alphanumeric form as they appear in the original data records, except for the missing data which were converted to standard form as stated in item (f) above.

The data from Stations A111–A114 were received at the University of Illinois in September, 1988 in the form of three nine-track computer tapes. The format of the data records on tape is given in Appendix A. These data were recorded at 1-s intervals for certain selected time periods which are listed in Appendix E. Recall that three of the stations (A111-A113) have wind speed and direction instruments at the 10-m level, but lack temperature measurements. Station A114, on the other hand, serves as both (a) a micrometeorological instrument tower with wind and temperature measurements at the 2-, 4-, 8-, 16- and 30-m levels, and (b) two surface stations with wind speed and direction measurements made at the 10- and 30-m levels. These surface stations are designated A114 and A115, with the Station A114 using the 10-m values and A115 using 30-m values.

The micrometeorological temperature measurements can be used to supplement the wind speed and direction values and thus provide a more complete data base. For Station A114 to be fully compatible with the other surface-station data, we need temperature data at the 2-m and 10-m levels. In addition, we might also wish to have a temperature at the 30-m level to complement the wind speed and direction measurement at that height for Station A115. The 2-m and 30-m temperatures recorded by the micrometeorological instrumentation can be used directly. However, no corresponding 10-m value exists. As a reasonable substitute, we have elected to use the measured value at the 8-m height rather than interpolating a 10-m temperature from the 8-m and 16-m data. We made this choice on the basis that a direct measurement is preferable to a calculated value. We must be careful to observe, however, that the two temperatures reported for Station A114 are actually measured at 2 and 8 m, not 2 and 10 m as is the case for all the other stations.

Finally, to fully integrate the 1-s measurements into the surface-station data base, a program was developed to determine 1-min averages similar to those calculated for the other stations by the dataloggers in the field. In computing these averages, we specified that at least 15 valid 1-s measurements were required within any given 1-min period in order for the corresponding 1-min average to be valid. This was done to avoid having a 1-min average based on only a few seconds of valid data and was implemented by noting that faulty data were marked on the original tape by a trailing "x". In converting the data to standard form, we used the string "-99999" to indicate bad and missing data.

To facilitate further data processing, a computer program was written to combine the data from all 15 individual surface stations into a single file for any user-selected time period. In this manner, it is possible to produce a condensed file of surface-station data for any given smoke or tracer trial. The format of the condensed data is as follows:

```
TIME STAMP (YY:JJJ:HH:MM)
    DATA FOR STATION A101
    DATA FOR STATION A102
              •
              •
              •
    DATA FOR STATION A114
    DATA FOR STATION A115
```

A more complete description and sample of the record format is given in Appendix C.

3.1.3 Synopsis of Surface-station Data

Averages of the surface-station data were computed for each of the 12 smoke releases. In addition, two quantities commonly used to characterize the turbulent nature of the boundary layer were calculated from the surface-station data. One is the standard deviation of the horizontal wind direction σ_θ, and the other is the bulk Richardson number which can be calculated for those stations where two temperature measurements are available. For the purposes of this evaluation, the analysis was carried out for the period beginning with the start of the smoke release and ending at 10 min after the smoke release was terminated. The averaging period was extended past the end of the smoke release to allow time for the smoke plume to move off the sampling grid.

Scalar and Vector Averages

Scalar averaging can be used for the wind speed and any of the several temperature values. For example, the scalar-mean wind speed S is determined from

$$S = \frac{1}{N} \sum_{n=1}^{N} s_i \ , \tag{3.1}$$

where s_i represents an individual 1-min scalar-average wind speed and N is the number of valid measurements included in the average. Alternatively, vector averaging can be used to determine the mean wind velocity. To determine the vector-mean wind speed, one first computes the component averages u_1 and u_2 as follows.

$$U_1 = \frac{1}{N} \sum_{n=1}^{N} u_i (\cos \theta_i) \tag{3.2}$$

and

$$U_2 = \frac{1}{N} \sum_{n=1}^{N} u_i (\sin \theta_i) \ , \tag{3.3}$$

where θ_i represents an individual 1-min average wind direction. The vector-mean wind speed U and vector-mean wind direction θ are then given by

$$U = \sqrt{U_1^2 + U_2^2} \tag{3.4}$$

and

$$\theta = \arctan (U_2, U_1) \ , \tag{3.5}$$

where arctan represents the full-circle arctangent function yielding values between 0° and 360°.

Once the vector-mean wind direction θ is determined, the individual wind velocity measurements can be resolved into their mean-wind component u_i and their cross-wind component v_i given by

$$u_i = s_i \cos (\theta_i - \theta) \tag{3.6}$$

and

$$v_i = s_i \sin (\theta_i - \theta) \ . \tag{3.7}$$

It is easily shown that the (scalar) mean value of u is the vector-mean wind speed U and that the (scalar) mean value of v is 0. Because the cosine function appearing in Eqn. 3.6 is always less than or equal to one, it follows that each u_i is less than or equal to each s_i and thus that U is less than or equal to S, the equality being true only if the wind direction is constant (i.e., $\theta_i = \theta$, for all i).

Although surface-station data are primarily used to characterize the mean wind and temperature fields, estimates of atmospheric stability can be obtained from either of two alternative methods. The first method uses the variation in the horizontal wind direction σ_θ, and the second method uses the vertical temperature gradient to estimate stability through the Richardson number concept. We shall first discuss the determination of σ_θ, and then more fully explain the calculation of the Richardson number.

Standard Deviation of Horizontal Wind Direction

Although widely used, the computation of σ_θ is fraught with several difficulties. One problem is caused by the fact that θ is periodic. Consider, as a simple illustration of this problem, the average of the two measurements: 355° and 5°. The mean computed by conventional methods is 180°, and the standard deviation is 247.5° which is clearly incorrect. The correct results are 0° and 7.1°, respectively. To avoid this problem, one can first determine the vector mean wind direction θ as noted above and then compute the standard deviation from the individual values d_i given by

$$d_i = (\theta_i - \theta + 540°) \bmod 360° - 180° \;, \qquad (3.8)$$

where the modulo arithmetic indicated in Eqn. 3.8 has the net effect of mapping each individual deviation into the interval (-180°, +180°). For example, a simple arithmetic difference of 270° becomes an adjusted difference of 90°.

Some authors define the root mean square of these deviations as σ_θ. However, this definition introduces a systematic bias in the results because the mean deviation is not 0. For this reason, we employ the following definition which removes the effect of the non-zero mean deviation.

$$\sigma_{\theta,1\text{-min}} = \left[\left(\frac{1}{N-1}\sum_{i=0}^{N} d_i^2\right) - \frac{N}{N-1}\left(\frac{1}{N}\sum_{i=0}^{N} d_i\right)^2\right]^{1/2} . \qquad (3.9)$$

Here, we use the special notation $\sigma_{\theta,1\text{-min}}$ to emphasize the fact that the surface data consist of 1-min averages of the wind speed and direction. When such averages are used, the value of σ_θ is systematically underestimated. The true or total variance is actually the sum of two terms: (i) the variance of the averages as above and (ii) the mean of the individual variances associated with each average. The dataloggers used for the individual surface stations did not compute σ_θ directly. Instead, they used an approximation that allowed them to compute σ_θ every minute using the scalar-averaged and vector-averaged wind speeds. This approximation is

$$\sigma_{\theta i} \approx \frac{180° \sqrt{2}}{\pi} \left(1 - \frac{u_i}{s_i}\right)^{1/2}$$

$$\approx 81° \left(1 - u_i / s_i\right)^{1/2} \tag{3.10}$$

For deviations less than 40°, the error associated with this approximation is less than 1%. The error substantially increases for larger deviations and is 10% at 60°. Finally, the expression for σ_θ thus becomes

$$\sigma_\theta = \left[\sigma^2_{\theta,1\text{-min}} + \frac{1}{N} \sum_{i=0}^{N} \sigma^2_{\theta i}\right]^{1/2} . \tag{3.11}$$

Richardson Number

The Richardson number characterizes the relative importance of buoyancy in influencing boundary-layer dynamics. Large negative values of the Richardson number are indicative of unstable stratification and thus convective turbulence. On the other hand, large positive values denote stable stratification which tends to suppress turbulent mixing. A Richardson number of zero indicates neutral stratification.

Two forms of the Richardson number are commonly discussed. The *gradient* Richardson number Ri is defined in terms of the vertical density and velocity gradients as follows.

$$Ri = \frac{g\,(\partial\rho/\partial z)}{\rho\,(\partial U/\partial z)^2} , \tag{3.12}$$

where g is the acceleration of gravity, ρ is density and z is vertical position. The gradient Richardson number is a function of vertical position and is virtually impossible to determine empirically. The *bulk* Richard number Ri_B is defined for a specific layer, and is based on the change in wind speed and temperature across that layer. Thus, the gradients appearing in Eqn. 3.12 are replaced by the corresponding finite differences ($\partial\rho/\partial z$ by $\Delta\rho/\Delta z$ and $\partial U/\partial z$ by $\Delta U/\Delta z$) and the density appearing in Eqn. 3.12 is replaced by the average density across the layer $\bar{\rho}$. Thus, we we may write

$$Ri_B = \frac{g\ (\Delta\rho/\Delta z)}{\bar{\rho}\ \ (\Delta U/\Delta z)^2} . \tag{3.13}$$

For the layer beginning at the ground and extending to a height of z_u (usually 10 m), we have

$$\frac{\Delta U}{\Delta z} = \frac{U}{z_u} \tag{3.14}$$

and

$$\frac{\Delta\rho}{\Delta z} = \frac{\rho(z_u) - \rho(0)}{z_u} , \tag{3.15}$$

from which it follows that

$$Ri_B = \frac{g\ z_u\ [\rho(z_u) - \rho(0)]}{\bar{\rho}\ \ U^2} , \tag{3.16}$$

where $\bar{\rho} = [\rho(z_u) + \rho(0)]\ /\ 2$.

Density depends on both temperature and pressure, although the later dependency can be accurately approximated using a hydrostatic analysis. Since measuring the air temperature at zero height above the ground is unreasonable, the vertical density difference is usually determined over only part of the layer. The most common practice is to measure wind speed and temperature at a height of 10 m and then measure the difference in temperature between the the 10-m and 2-m levels. Other options are possible, however. In our case for instance, we use the 2-m and 8-m temperatures to compute the bulk Richardson number at Station A114. Since the density gradient varies slowly with vertical position, the error thus introduced is negligible. For the general case in which temperature is measured at two heights z_{T1} and z_{T2} and the wind speed U is measured at height z_u, we may write

$$Ri_B = \frac{g\, z_u^2\, [\rho(z_{T1}) - \rho(z_{T2})]}{\bar{\rho}\; U^2\, (z_{T1} - z_{T2})} \,. \tag{3.17}$$

Results and Discussion

A synopsis of the surface-station data for each of the 12 smoke trials is given in Tables 3.3 - 3.14. Here, the string "-99999" indicates that more than half of the minutes in the averaging period were bad. For those cases with less than 50% bad data, the number of bad minutes is explicitly indicated. Moreover, the notation "N/A" indicates that a particular item was not measured or is not computable.

Examination of these results reveals that the maximum wind speed varies between about 3 and 6 m/s. For the daytime trials, the range of wind speeds over the test area is within a factor of 3, whereas the variation can be as much as a factor of 10 at night. The temperatures follow the expected diurnal characteristics of the site being between roughly 10 °C and 15 °C for the nighttime and early morning tests and between roughly 25 °C and 40 °C for the daytime tests. The temperature inhomogeneity for the nighttime and early morning tests is larger than for the daytime tests. Specifically, the inhomogeneity is seen to be between 5 °C and 12 °C for the nighttime and early morning trials, but typically less than 2 °C for the daytime trials. The value of σ_θ is apparently smaller for the stable nighttime and early morning releases, although a few very large values of σ_θ are seen at night when wind speeds are low. This reflects the problems associated with defining σ_θ under light wind conditions. The Richardson number shows significant inhomogeneity (as much as a factor of 100) across the test area under stable nighttime and early morning conditions. In contrast, the inhomogeneity under unstable daytime conditions is much smaller being consistently less than a factor of 10.

The considerable inhomogeneity of the surface-station data underscores not only the complexity of the wind field in this setting but also the very difficult problem of characterizing the atmospheric boundary layer in simple terms.

Table 3.3 Synopsis of surface-station data for Test 0921871. Smoke was released from 14:30 to 15:00. The unstable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	-99999	-99999	-99999	-99999	-99999	-99999	-99999	-99999
A102	3.510	3.139	306.3	27.97	38.15	39.03	53.60	-0.020
A103	-99999	-99999	-99999	·99999	-99999	N/A	N/A	N/A
A104	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A105	3.951	3.701	308.5	20.99	38.04	38.85	53.14	-0.015
A106	3.474	3.214	288.3	26.19	38.26	39.16	49.90	-0.022
A107	3.156	2.883	320.4	24.39	38.54	39.40	53.67	-0.025
A108	4.172	3.982	280.7	19.20	37.94	38.79	51.02	-0.014
A109	[illegible]376	3.668	295.1	25.87	36.87	38.27	55.57	-0.028
A110	3.771	3.529	332.9	20.93	37.19	38.08	51.51	-0.018
A111	5.902	5.536	318.9	20.65	N/A	N/A	N/A	N/A
A112	3.912	3.714	318.1	18.05	N/A	N/A	N/A	N/A
A113	4.097	3.391	274.2	41.97	N/A	N/A	N/A	N/A
A114	4.329	3.951	297.7	25.18	38.65	39.17	N/A	-0.006
A115	4.659	4.290	298.5	23.92	38.28	39.17	N/A	N/A

<u>Notes:</u>

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.

2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.

3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.

4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.4 Synopsis of surface-station data for Test 0923871. Smoke was released from 14:00 to 15:31. The smoke moved off the grid at 14:50. The unstable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	2.867	2.374	296.3	42.94	30.20	30.70	48.24	-0.017
A102	2.718	2.398	275.9	30.29	29.84	30.82	50.84	-0.039
A103	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A104	2.512	2.213	236.6	43.99	30.07	N/A	N/A	N/A
A105	2.465	2.094	276.2	34.83	29.56	30.29	49.50	-0.035
A106	2.566	2.370	290.5	23.86	30.27	31.25	45.70	-0.044
A107	1.954	1.417	334.1	66.07	30.58	31.68	50.12	-0.086
A108	2.347	2.066	303.0	34.87	30.02	31.06	48.63	-0.057
A109	2.357	2.299	265.7	20.53	29.03	30.14	52.04	-0.060
A110	2.205	1.523	227.5	49.67	29.09	29.94	48.33	-0.052
A111	3.733	3.024	315.2	49.26	N/A	N/A	N/A	N/A
A112	2.559	2.127	320.6	42.86	N/A	N/A	N/A	N/A
A113	3.406	3.048	246.1	29.66	N/A	N/A	N/A	N/A
A114	3.245	2.905	269.4	27.57	30.41	31.11	N/A	-0.016
A115	3.377	3.060	264.3	26.55	30.06	31.11	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.5 Synopsis of surface-station data for Test 0925871. Smoke was released from 00:18 to 01:03. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.182	1.099	121.7	22.36	16.41	15.65	14.67	0.204
A102	0.389	0.328	66.64	48.47	15.59	14.20	12.76	3.308
A103	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A104	2.770	2.641	52.73	17.08	15.62	N/A	N/A	N/A
A105	2.370	2.332	118.6	10.28	17.29	17.02	17.80	0.021
A106	2.079	1.967	88.00	21.51	16.51	16.00	18.17	0.046
A107	1.622	1.550	165.5	17.07	15.99	15.17	15.92	0.116
A108	1.932	1.889	114.4	11.76	15.27	14.29	17.08	0.097
A109	1.954	1.944	55.65	10.94	19.53	19.25	17.84	0.031
A110	2.002	1.978	96.37	9.143	18.90	18.45	18.73	0.044
A111	0.324	0.323	190.2	0.208	N/A	N/A	N/A	N/A
A112	3.085	3.070	155.8	5.585	N/A	N/A	N/A	N/A
A113	3.041	3.011	99.96	8.009	N/A	N/A	N/A	N/A
A114	0.468	0.385	71.66	53.36	15.56	14.35	N/A	1.578
A115	1.307	1.291	66.47	10.46	16.24	14.35	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.
5. 1 bad minute was excluded in computing the 2-m temperature for Station A114.
6. 3 bad minutes were excluded in computing the 10-m temperature for Station A114.
7. 1 bad minute was excluded in computing the 10-m temperature for Station A115.
8. 2 bad minutes were excluded in computing the 10-m temperature for Station A115.

Table 3.6 Synopsis of surface-station data for Test 0926871. Smoke was released from 12:00 to 13:07. The unstable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	4.856	4.721	302.4	34.41	25.34	26.22	41.64	-0.011
A102	3.735	3.331	299.7	40.65	25.40	26.27	44.77	-0.019
A103	4.242	3.933	238.4	30.15	26.78	N/A	N/A	N/A
A104	2.486	1.922	249.5	59.97	25.96	N/A	N/A	N/A
A105	4.214	3.961	314.5	36.38	25.15	26.08	41.25	-0.016
A106	3.538	3.263	291.0	34.14	25.69	26.64	37.51	-0.023
A107	3.043	2.796	316.6	41.13	25.80	26.68	45.58	-0.028
A108	4.032	3.871	279.9	32.51	25.26	26.26	41.91	-0.019
A109	2.688	2.576	294.4	35.75	24.20	25.75	45.72	-0.067
A110	3.786	3.552	315.3	42.11	24.25	25.23	42.21	-0.021
A111	6.505	6.343	316.6	30.23	N/A	N/A	N/A	N/A
A112	4.198	4.057	313.6	28.68	N/A	N/A	N/A	N/A
A113	3.666	3.098	308.2	44.04	N/A	N/A	N/A	N/A
A114	4.475	4.026	294.4	46.78	26.21	26.79	N/A	-0.007
A115	4.722	4.353	291.0	27.09	25.81	26.79	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.
5. 1 bad minute was excluded in computing the vector speed and direction for Station A112.
6. 1 bad minute was excluded in computing the vector speed and direction for Station A113.

Table 3.7 Synopsis of surface-station data for Test 0927871. Smoke was released from 03:19 to 03:39. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.055	0.920	117.6	28.17	13.23	11.75	8.263	0.480
A102	0.348	0.218	91.02	69.02	11.50	9.928	5.349	4.696
A103	2.880	2.821	64.33	11.94	12.77	N/A	N/A	N/A
A104	3.819	3.741	54.14	11.27	12.55	N/A	N/A	N/A
A105	2.251	2.216	113.5	10.01	16.76	16.06	13.35	0.052
A106	2.019	1.959	103.1	19.10	12.60	11.38	13.00	0.110
A107	1.371	1.325	139.0	15.14	12.04	10.27	9.758	0.339
A108	1.866	1.833	98.54	10.70	11.95	9.737	11.61	0.226
A109	0.868	0.746	20.11	32.54	21.65	20.87	12.93	0.377
A110	0.646	0.555	138.0	35.80	19.70	17.82	14.24	1.571
A111	2.507	2.392	145.4	17.44	N/A	N/A	N/A	N/A
A112	2.101	2.059	156.8	14.50	N/A	N/A	N/A	N/A
A113	3.483	3.457	86.30	7.269	N/A	N/A	N/A	N/A
A114	0.671	0.556	74.32	36.88	11.42	9.235	N/A	1.372
A115	1.213	1.124	13.47	23.32	13.05	9.235	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.
5. 3 bad minutes were excluded in computing the 10-m temperature for Station A115.

Table 3.8 Synopsis of surface-station data for Test 0927872. Smoke was released from 06:44 to 06:54. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.232	1.079	132.3	31.24	11.56	10.39	6.403	0.283
A102	0.648	0.425	98.63	51.68	9.870	8.232	3.937	1.418
A103	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A104	3.601	3.568	57.50	7.609	10.67	N/A	N/A	N/A
A105	2.227	2.178	113.9	12.35	15.72	14.96	11.88	0.057
A106	2.836	2.780	99.05	11.61	11.86	10.98	11.52	0.041
A107	1.818	1.765	146.9	13.74	10.51	8.841	7.890	0.183
A108	2.562	2.541	102.0	7.438	9.763	7.847	10.05	0.105
A109	1.338	1.311	114.6	21.87	20.28	19.25	10.93	0.208
A110	2.002	1.994	146.9	5.190	18.02	16.39	13.11	0.144
A111	2.402	2.232	158.0	23.00	N/A	N/A	N/A	N/A
A112	3.096	3.077	157.8	6.425	N/A	N/A	N/A	N/A
A113	3.100	3.062	82.58	9.310	N/A	N/A	N/A	N/A
A114	1.022	0.901	76.79	32.00	9.635	8.253	N/A	0.393
A115	1.509	1.488	9.496	9.026	11.59	8.253	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.

2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.

3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.

4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

5 1 bad minute was excluded in computing the vector speed and direction for Station A109.

Table 3.9 Synopsis of surface-station data for Test 0928871. Smoke was released from 10:29 to 10:54. The unstable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	2.740	2.702	301.4	9.667	25.70	26.32	37.32	-0.024
A102	2.585	2.542	265.9	10.54	26.18	27.01	40.31	-0.037
A103	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A104	2.517	2.430	226.7	14.73	26.90	N/A	N/A	N/A
A105	2.058	1.885	286.5	23.30	26.46	27.09	36.00	-0.043
A106	2.313	2.267	259.4	11.45	26.70	27.47	31.06	-0.042
A107	1.864	1.727	326.7	22.58	27.29	28.00	38.64	-0.059
A108	2.213	2.112	308.9	16.96	26.87	28.02	32.22	-0.072
A109	-99999	-99999	-99999	-99999	-99999	-99999	-99999	-99999
A110	1.687	1.637	324.3	13.69	25.76	26.45	38.11	-0.071
A111	3.700	3.650	306.6	9.499	N/A	N/A	N/A	N/A
A112	2.355	2.139	327.2	24.96	N/A	N/A	N/A	N/A
A113	2.934	2.831	236.6	15.62	N/A	N/A	N/A	N/A
A114	3.136	3.101	258.3	8.946	26.77	27.18	N/A	-0.09
A115	2.508	2.461	286.1	11.40	26.54	27.18	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.10 Synopsis of surface-station data for Test 0930871. Smoke was released from 06:48 to 07:28. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.528	1.441	121.9	19.15	18.89	17.12	12.07	0.265
A102	0.946	0.853	78.45	26.80	18.02	15.25	9.410	1.072
A103	2.531	2.453	82.01	13.71	18.09	N/A	N/A	N/A
A104	3.000	2.862	42.17	16.26	17.73	N/A	N/A	N/A
A105	3.110	3.048	116.3	11.39	20.81	20.12	16.75	0.026
A106	3.217	3.161	79.98	10.83	19.61	18.79	16.72	0.029
A107	1.942	1.854	159.7	17.43	18.34	15.83	13.11	0.231
A108	2.405	2.329	112.4	14.75	17.21	14.55	14.19	0.160
A109	-99999	-99999	-99999	-99999	-99999	-99999	-99999	-99999
A110	1.712	1.688	112.4	9.821	25.20	23.22	17.60	0.231
A111	3.137	3.037	155.9	14.54	N/A	N/A	N/A	N/A
A112	3.746	3.730	158.3	5.228	N/A	N/A	N/A	N/A
A113	4.410	4.295	94.20	13.11	N/A	N/A	N/A	N/A
A114	1.465	1.391	74.19	19.69	17.79	15.41	N/A	0.306
A115	2.052	2.005	74.27	13.22	18.96	15.41	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.11 Synopsis of surface-station data for Test 1001871. Smoke was released from 06:52 to 07:32. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.359	1.216	119.4	26.82	20.32	18.56	14.08	0.332
A102	0.944	0.770	93.50	52.05	19.32	17.55	11.35	0.696
A103	2.252	2.009	91.60	28.82	19.80	N/A	N/A	N/A
A104	3.922	3.642	52.45	22.01	20.36	N/A	N/A	N/A
A105	2.803	2.742	120.6	12.08	21.98	21.31	17.79	0.032
A106	3.438	3.313	78.56	18.52	20.53	20.12	18.73	0.014
A107	2.322	2.225	161.2	16.78	19.27	18.20	14.86	0.071
A108	2.745	2.669	112.1	13.56	18.02	16.13	15.49	0.088
A109	2.949	2.926	61.08	11.35	27.33	26.31	19.28	0.041
A110	1.979	1.762	100.8	32.83	24.80	23.29	19.55	0.133
A111	2.787	2.686	148.0	15.32	N/A	N/A	N/A	N/A
A112	3.733	3.693	157.5	8.690	N/A	N/A	N/A	N/A
A113	4.103	3.716	90.89	26.16	N/A	N/A	N/A	N/A
A114	1.379	1.221	81.78	28.83	19.05	17.45	N/A	0.234
A115	2.243	2.197	80.74	12.32	20.25	17.45	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.12 Synopsis of surface-station data for Test 1002871. Smoke was released from 07:17 to 07:47. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.542	1.484	112.7	15.33	18.90	17.78	14.99	0.170
A102	0.745	0.685	76.10	34.68	18.01	16.33	12.46	1.067
A103	1.989	1.933	85.07	13.22	18.41	N/A	N/A	N/A
A104	3.249	3.102	51.00	17.30	18.78	N/A	N/A	N/A
A105	2.930	2.897	115.1	8.395	20.48	20.02	18.37	0.021
A106	2.157	2.068	94.06	16.23	18.73	18.11	18.11	0.050
A107	1.513	1.429	159.6	19.27	18.28	16.26	14.72	0.308
A108	1.944	1.890	104.3	13.75	17.37	15.22	15.97	0.199
A109	2.217	2.172	56.79	14.97	24.80	24.15	18.51	0.049
A110	1.409	1.374	104.5	12.76	23.16	21.94	19.37	0.216
A111	2.914	2.855	148.7	11.38	N/A	N/A	N/A	N/A
A112	3.189	3.177	157.3	5.066	N/A	N/A	N/A	N/A
A113	3.534	3.482	100.7	9.951	N/A	N/A	N/A	N/A
A114	1.257	1.219	72.34	18.44	18.01	16.78	N/A	0.220
A115	1.915	1.887	74.17	10.57	18.77	16.78	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.
5. 1 bad minute was excluded in computing the 10-m temperature for Station A111

Table 3.13 Synopsis of surface-station data for Test 1002872. Smoke was released from 12:16 to 12:34. The unstable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	2.098	2.005	283.6	17.77	30.09	30.50	43.57	-0.024
A102	2.798	2.710	247.9	14.51	30.07	30.95	43.81	-0.033
A103	3.131	2.975	240.9	18.61	31.97	N/A	N/A	N/A
A104	2.951	2.794	220.3	18.88	30.58	N/A	N/A	N/A
A105	2.214	2.023	283.1	24.14	29.85	30 55	47.25	-0.041
A106	2.531	2.446	260.8	16.39	30.39	31.34	41.06	-0.044
A107	1.834	1.670	311.0	28.90	30.81	31.64	48.17	-0.072
A108	1.757	1.513	277.6	35.32	30.47	31.59	46.11	-0.109
A109	2.021	1.962	265.5	20.12	29.72	30.96	49.18	-0.092
A110	1.844	1.720	320.0	20.90	29.03	29.84	46.64	-0.070
A111	2.368	2.666	289.3	22.35	N/A	N/A	N/A	N/A
A112	0.225	0.190	74.11	32.29	N/A	N/A	N/A	N/A
A113	3.574	3.419	226.2	17.10	N/A	N/A	N/A	N/A
A114	3.506	3.421	244.2	12.51	30.40	31.15	N/A	-0.014
A115	3.430	3.354	250.3	12.07	30.05	31.15	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

Table 3.14 Synopsis of surface-station data for Test 1003871. Smoke was released from 06:56 to 07:27. The stable release point was used.

Station	S [m/s]	U [m/s]	θ [°]	σ_θ [°]	T_{10m} [C]	T_{2m} [C]	T_{soil} [C]	Ri_b
A101	1.153	1.045	114.8	25.19	18.29	16.96	14.19	0.355
A102	0.659	0.432	122.6	63.18	17.68	15.38	12.98	1.851
A103	-99999	-99999	-99999	-99999	-99999	N/A	N/A	N/A
A104	2.830	2.754	63.14	12.70	17.96	N/A	N/A	N/A
A105	2.716	2.682	131.1	9.152	20.67	19.93	17.78	0.037
A106	2.394	2.133	81.94	50.65	18.93	18.26	18.02	0.044
A107	1.917	1.822	163.3	18.12	18.57	17.43	14.82	0.111
A108	3.032	2.977	115.3	10.78	18.05	17.04	16.09	0.040
A109	3.005	2.984	84.22	10.33	25.49	24.57	17.87	0.036
A110	2.148	2.104	96.12	21.00	23.51	22.46	18.81	0.081
A111	2.596	2.468	144.2	18.18	N/A	N/A	N/A	N/A
A112	3.419	3.389	157.1	7.796	N/A	N/A	N/A	N/A
A113	3.676	3.579	79.30	13.41	N/A	N/A	N/A	N/A
A114	0.827	0.584	116.6	62.96	17.28	15.84	N/A	0.579
A115	1.611	1.579	85.52	13.62	18.56	15.84	N/A	N/A

Notes:

1. All wind speed and direction measurements are at 10 m, except for Station A115 which is at 30 m.
2. All upper temperature measurements (T_{10m}) are at 10 m as implied by the subscript, except for Station A114 which is at 8 m and Station A115 which is at 30 m.
3. All lower temperature measurements (T_{2m}) are at 2 m as implied by the subscript.
4. Soil temperature measurements (T_{soil}) are a depth of 0.1 m.

3.2 Micrometeorological Data

3.2.1 Description of the Micrometeorological Data

As previously noted, Station A114/115 served as both a dual-height surface station and as a micrometeorological instrument tower. The micrometeorological data consist of wind and temperature measurements taken at five heights: 2 m, 4 m, 8 m, 16 m and 30 m. Propellor anemometers were used on all five levels to measure the three components of the wind velocity. Temperature sensors were located on all five levels as well. In addition, three laser anemometers were positioned on the tower to determine the bulk flow rate through the valley. Data were taken at the rate of 1 Hz and recorded using a centralized data acquisition system. The data were provided to us on three nine-track computer tapes as described in Section 3.1.2. The format and a sample of the data record appear in Appendix A.3.

3.2.2 Synopsis of the Micrometeorological Data

The synopsis of the micrometeorological data was prepared in much the same manner as was previously described for the surface-station data. Three important distinctions exist, however.

1. The analysis of the micrometeorological data was completed using the 1-s data read directly from tape, whereas the analysis of the surface-station data was made using 1-min averages. Thus, no adjustment to σ_θ (as in Eqn. 3.11) is necessary in this case.

2. The wind velocity was specified by the three Cartesian components u_1, u_2, and u_3, instead of speed and direction. In the first step of the analysis, averages of the three components are computed separately from the following expressions.

$$U_1 = \frac{1}{N} \sum_{n=1}^{N} u_{1i} \quad , \tag{3.18}$$

$$U_2 = \frac{1}{N} \sum_{n=1}^{N} u_{2i} \quad , \tag{3.19}$$

and

$$U_3 = \frac{1}{N} \sum_{n=1}^{N} u_{3i} \quad , \tag{3.20}$$

where u_{1i}, u_{2i}, u_{3i} represent individual 1-s measurements. Next, the vector-mean wind speed and direction are found from Eqns. 3.4 and 3.5 which are repeated here for the convenience of the reader.

$$U = \sqrt{U_1^2 + U_2^2} \tag{3.4}$$

$$\theta = \arctan\,(U_2, U_1)\ , \tag{3.5}$$

Third, each of the 1-s wind velocity vectors is transformed into its mean-wind, cross-wind and vertical components using the three relationships

$$u_i = s_i \cos\,(\theta_i - \theta)\ , \tag{3.6}$$

$$v_i = s_i \sin\,(\theta_i - \theta)\ , \tag{3.7}$$

and

$$w_i = u_{3i}\ , \tag{3.21}$$

where

$$s_i = \sqrt{u_{1i}^2 + u_{2i}^2}\ . \tag{3.22}$$

Lastly, standard deviations are computed for the components u, v, and w.

3. The averaging period was chosen to assure compatibility with the spectral analysis of the u, v and w fluctuations presented in Section 3.2.3. Thus, the averaging period is not exactly the same as that used for the surface station data, although the net effect of this difference is expected to be small.

The synopsis of the micrometeorological data for each of the 12 smoke trials is given in Tables 3.15 to 3.27. Also, vertical profiles of wind speed and temperature based on these tabulated data are shown in Figs. 3.1 to 3.6. In the tables, the string "-99999" is used to indicate that a valid average could not be computed. It is readily apparent that there are several occasions when one or more of the tower levels was inoperative. The 4-m level is particularly troublesome in this regard. Also, a significant number of bad data are present in the original records for some cases. Despite this limitation, we felt that a valid average could be obtained in most instances, and have reported the results as such. The effect of bad and missing data will be more closely examined as part of future data analysis, however.

Table 3.15 Synopsis of the micrometeorological data for Test 0921871. Smoke was released from 14:30 to 15:00. The unstable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	2.639	3.000	-0.0620	301.9	39.17
4 m	2.915	3.283	-0.1325	298.1	38.79
8 m	3.184	3.553	-0.1555	297.6	38.65
16 m	3.318	3.697	-0.3584	300.7	38.50
30 m	3.331	3.748	-0.1245	301.5	38.28

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	1.011	1.067	1.467	0.2114	28.9	0.24
4 m	1.150	1.183	1.535	0.2965	28.3	0.24
8 m	1.194	1.205	1.586	0.4014	27.3	0.23
16 m	1.167	1.177	1.639	0.5695	27.0	0.23
30 m	1.198	1.173	1.700	0.7115	28.2	0.20

Table 3.16 Synopsis of the micrometeorological data for Test 0923871. Smoke was released from 14:00 to 15:31. The smoke moved off the grid at 14:50. The unstable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	2.120	2.382	0.0086	270.4	31.11
4 m	2.214	2.495	-0.0631	269.0	30.62
8 m	2.382	2.655	0.0078	269.6	30.41
16 m	2.458	2.588	-0.1515	276.1	30.26
30 m	2.512	2.771	0.0889	267.5	30.06

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	1.044	0.950	0.997	0.1911	31.4	0.35
4 m	1.099	1.002	1.059	0.2452	31.6	0.34
8 m	1.138	1.045	1.082	0.3162	29.1	0.34
16 m	1.095	1.063	0.765	0.4372	20.4	0.31
30 m	1.082	0.952	1.052	0.5852	28.2	0.30

Table 3.17 Synopsis of the micrometeorological data for Test 0925871. Smoke was released from 00:18 to 01:03. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.198	0.369	0.0230	121.0	14.35
4 m	0.229	0.363	0.0075	93.4	-99999
8 m	0.302	0.465	0.0242	67.0	15.56
16 m	0.577	0.631	-0.0539	78.4	15.91
30 m	1.203	1.218	0.0246	86.7	16.24

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.231	0.176	0.273	0.0553	70.4	0.46
4 m	0.213	0.186	0.262	0.0738	54.9	-99999
8 m	0.283	0.225	0.308	0.0586	64.2	0.35
16 m	0.316	0.285	0.215	0.0760	31.1	0.15
30 m	0.361	0.353	0.174	0.1537	11.6	0.18

Table 3.18 Synopsis of the micrometeorological data for Test 0926871. Smoke was released from 12:00 to 13:07. The unstable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	2.583	2.992	0.0210	293.1	26.79
4 m	-99999	-99999	-99999	-99999	-99999
8 m	3.156	3.560	-0.1115	292.0	26.21
16 m	3.295	3.682	-0.2265	296.7	26.07
30 m	3.286	3.691	0.0728	295.8	25.81

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	1.260	1.235	1.489	0.2403	33.4	0.79
4 m	-99999	-99999	-99999	-99999	-99999	-99999
8 m	1.436	1.382	1.600	0.4350	31.2	0.71
16 m	1.371	1.336	1.613	0.6119	29.2	0.69
30 m	1.372	1.301	1.624	0.7838	32.4	0.66

Table 3.19 Synopsis of the micrometeorological data for Test 0927871. Smoke was released from 03:19 to 03:39. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.474	0.628	0.0210	98.8	9.24
4 m	-99999	-99999	-99999	-99999	-99999
8 m	0.432	0.621	-0.0256	82.2	11.42
16 m	0.556	0.729	-0.0661	58.4	12.27
30 m	1.050	1.120	0.0726	83.1	13.05

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.365	0.263	0.326	0.0631	53.3	0.82
4 m	-99999	-99999	-99999	-99999	-99999	-99999
8 m	0 266	0.210	0.415	0.0817	48.4	0.32
16 m	0.225	0.248	0.482	0.0738	42.7	0.26
30 m	0.327	0.302	0.370	0.1573	22.0	0.32

Table 3.20 Synopsis of the micrometeorological data for Test 0927872. Smoke was released from 06:44 to 06:54. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.332	0.582	0.0163	101.0	8.25
4 m	-99999	-99999	-99999	-99999	-99999
8 m	0.589	0.770	-0.0395	73.6	9.64
16 m	0.968	1.058	-0.1090	72.1	10.52
30 m	1.358	1.377	0.0452	79.6	11.59

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.371	0.300	0.425	0.0714	62.1	0.65
4 m	-99999	-99999	-99999	-99999	-99999	-99999
8 m	0.491	0.410	0.417	0.1152	47.0	0.50
16 m	0.522	0.488	0.383	0.0654	27.3	0.31
30 m	0.377	0.371	0.218	0.1819	10.2	0.16

Table 3.21 Synopsis of the micrometeorological data for Test 0928871. Smoke was released from 10:29 to 10:54. The unstable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	2.517	2.549	0.0560	260.4	27.18
4 m	-99999	-99999	-99999	-99999	-99999
8 m	2.728	2.757	-0.0072	259.9	26.77
16 m	2.590	2.619	-0.1558	261.2	26.77
30 m	2.131	2.167	0.0117	262.2	26.54

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.511	0.501	0.386	0.1367	9.5	0.24
4 m	-99999	-99999	-99999	-99999	-99999	-99999
8 m	0.515	0.507	0.388	0.2148	8.6	0.18
16 m	0.552	0.539	0.369	0.2607	9.2	0.19
30 m	0.552	0.545	0.383	0.2977	11.0	0.22

Table 3.22 Synopsis of the micrometeorological data for Test 0930871. Smoke was released from 06:48 to 07:28. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.705	0.775	0.0188	91.4	15.41
4 m	0.829	0.889	0.0324	83.4	16.75
8 m	0.953	1.049	-0.0278	70.1	17.79
16 m	1.258	1.339	-0.0371	74.8	19.08
30 m	1.739	1.778	0.0390	81.0	18.96

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.397	0.374	0.294	0.0686	30.4	0.66
4 m	0.348	0.332	0.306	0.1071	25.3	0.44
8 m	0.330	0.301	0.418	0.0958	26.9	0.25
16 m	0.438	0.413	0.435	0.1270	22.7	0.20
30 m	0.532	0.512	0.342	0.2004	13.9	0.17

Table 3.23 Synopsis of the micrometeorological data for Test 1001871. Smoke was released from 06:52 to 07:32. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.329	0.593	0.0087	96.0	17.45
4 m	0.504	0.678	0.0096	88.1	18.32
8 m	0.669	0.844	-0.0181	78.3	19.05
16 m	1.164	1.286	-0.0010	85.4	19.61
30 m	1.915	1.951	0.0799	87.7	20.25

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.324	0.303	0.480	0.0900	67.0	0.67
4 m	0.334	0.364	0.477	0.1237	45.9	0.43
8 m	0.424	0.407	0.501	0.1253	42.6	0.31
16 m	0.524	0.506	0.528	0.1612	28.3	0.22
30 m	0.643	0.633	0.353	0.2252	12.0	0.24

Table 3.24 Synopsis of the micrometeorological data for Test 1002871. Smoke was released from 07:17 to 07:47. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.576	0.609	0.0156	94.9	16.78
4 m	0.671	0.698	0.0101	86.1	17.55
8 m	0.813	0.878	-0.0443	68.4	18.01
16 m	1.187	1.233	-0.0524	76.7	18.56
30 m	1.709	1.738	-0.0014	82.4	18.77

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.421	0.400	0.145	0.0616	37.4	0.47
4 m	0.437	0.422	0.151	0.0965	25.4	0.36
8 m	0.490	0.460	0.286	0.0963	30.6	0.30
16 m	0.543	0.506	0.272	0.1221	20.3	0.14
30 m	0.583	0.570	0.290	0.1821	11.9	0.30

Table 3.25 Synopsis of the micrometeorological data for Test 1002872. Smoke was released from 12:16 to 12:34. The unstable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	2.499	2.582	0.0605	245.3	31.15
4 m	2.533	2.623	-0.0406	242.2	30.69
8 m	2.700	2.775	0.0306	244.5	30.40
16 m	2.805	2.875	-0.1622	245.8	30.29
30 m	2.934	2.998	0.0266	246.8	30.05

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.705	0.689	0.630	0.1577	15.4	0.37
4 m	0.678	0.669	0.671	0.2004	15.7	0.31
8 m	0.686	0.680	0.633	0.2594	13.9	0.32
16 m	0.625	0.611	0.614	0.3651	13.1	0.31
30 m	0.530	0.513	0.602	0.4368	12.3	0.29

Table 3.26 Synopsis of the micrometeorological data for Test 1003871. Smoke was released from 06:56 to 07:27. The stable release point was used.

Level	U [m/s]	S [m/s]	W [m/s]	θ [°]	T [C]
2 m	0.202	0.589	0.0200	197.3	15.84
4 m	0.222	0.589	-0.0048	158.1	16.50
8 m	0.284	0.634	-0.0031	135.1	17.28
16 m	0.786	0.871	-0.0089	107.3	-99999
30 m	1.482	1.521	0.0704	94.7	18.56

Level	σ_u [m/s]	σ_s [m/s]	σ_v [m/s]	σ_w [m/s]	σ_θ [°]	σ_t [C]
2 m	0.465	0.247	0.388	0.0700	85.0	0.92
4 m	0.351	0.268	0.496	0.1103	70.3	0.78
8 m	0.389	0.255	0.484	0.1140	69.6	0.58
16 m	0.545	0.483	0.278	0.1472	48.6	-99999
30 m	0.696	0.682	0.316	0.2094	19.7	0.21

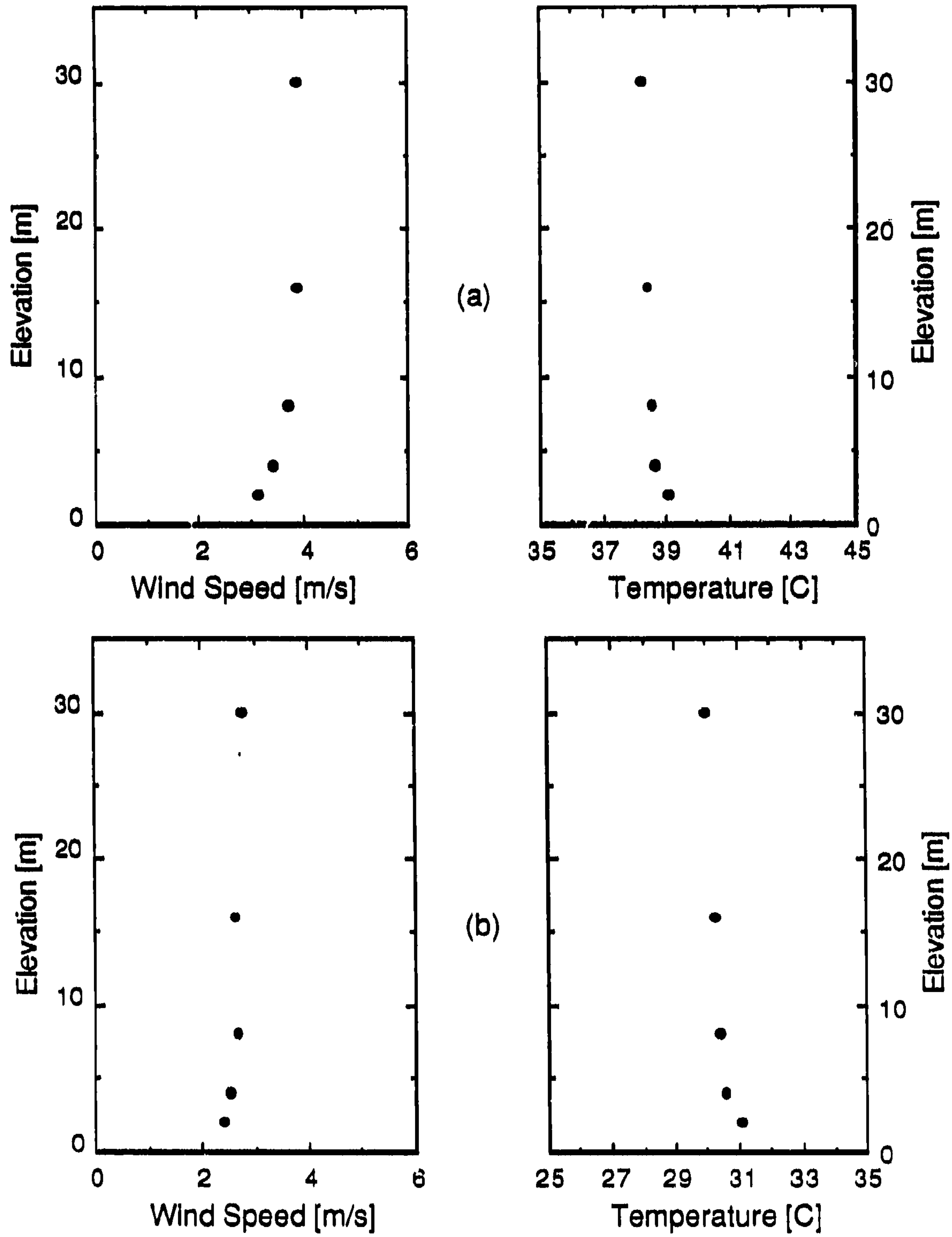


Figure 3.1 Vertical profiles of wind speed and temperature for (a) Test 0921871 and (b) Test 0923871.

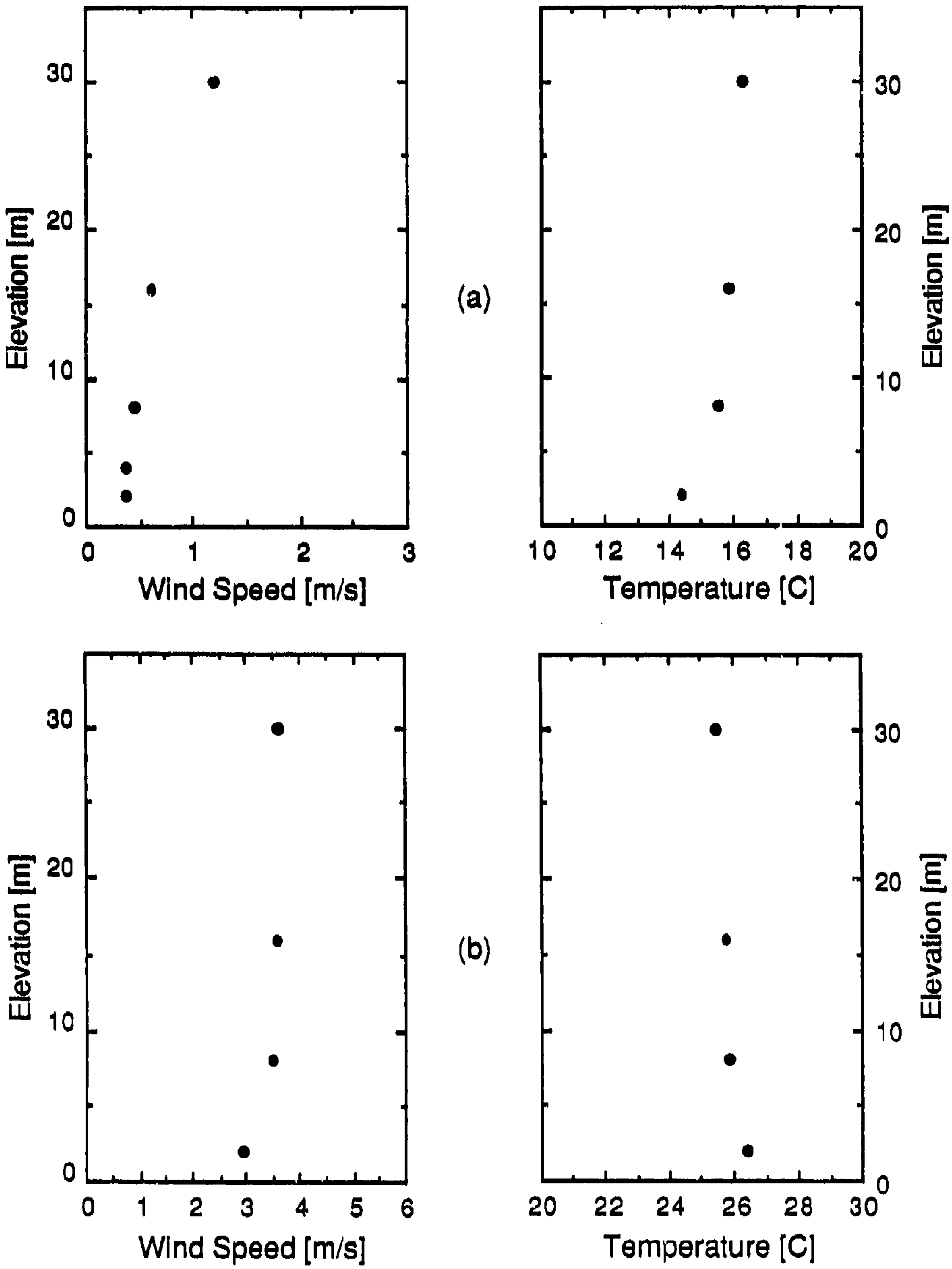


Figure 3.2 Vertical profiles of wind speed and temperature for (a) Test 0925871 and (b) Test 0926871.

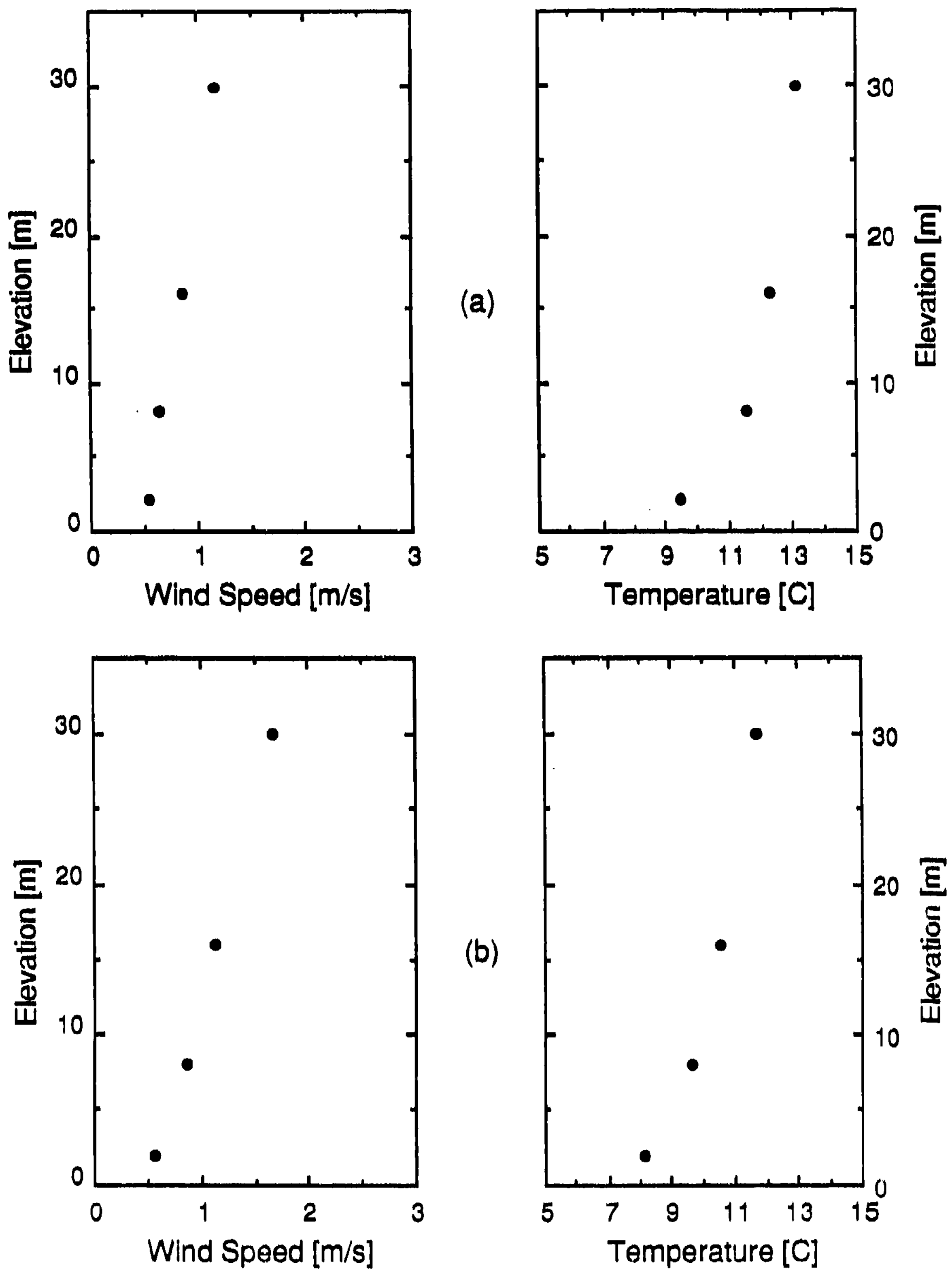


Figure 3.3 Vertical profiles of wind speed and temperature for (a) Test 0927871 and (b) Test 0927872.

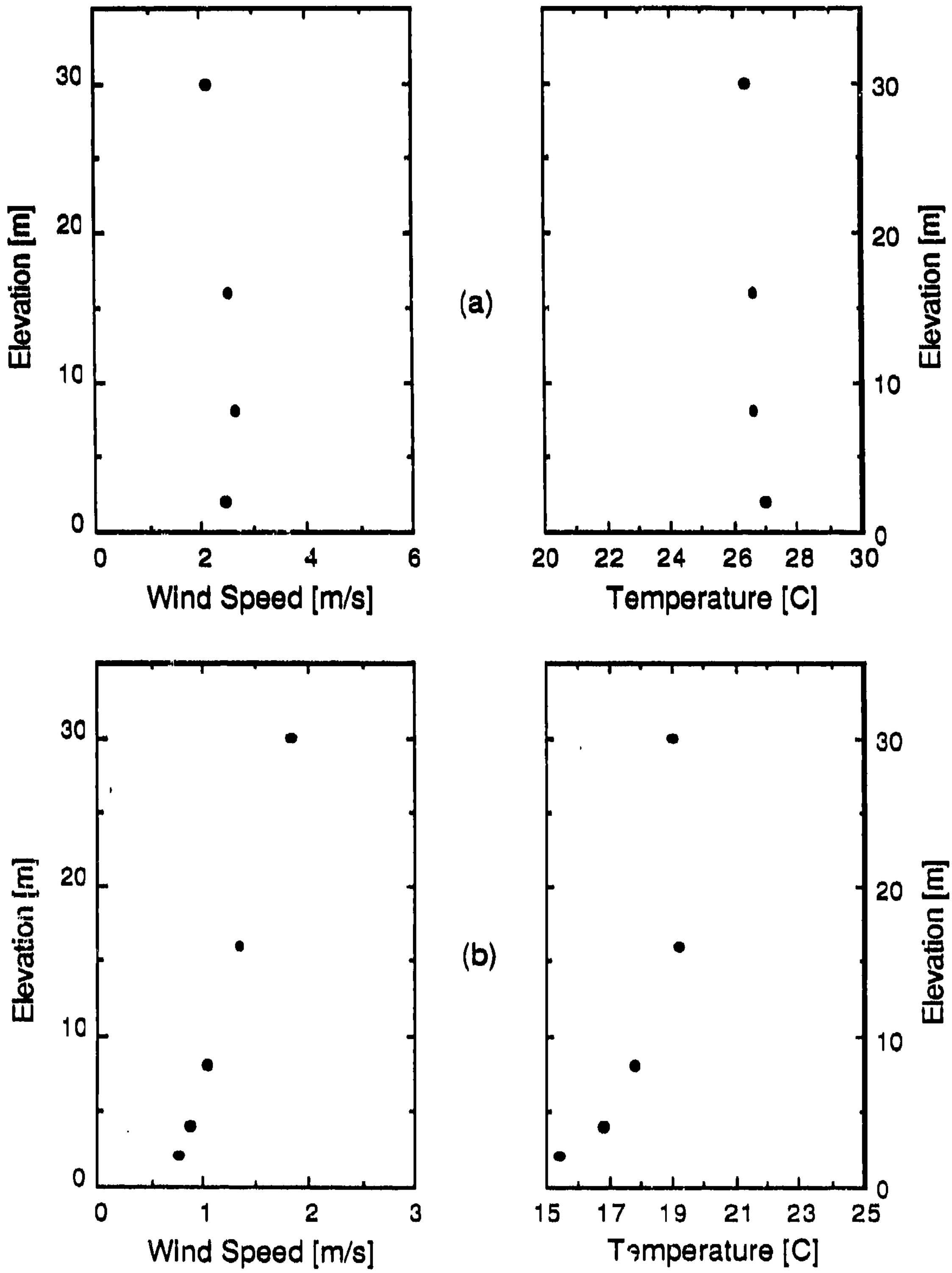


Figure 3.4 Vertical profiles of wind speed and temperature for (a) Test 0928871 and (b) Test 0930871.

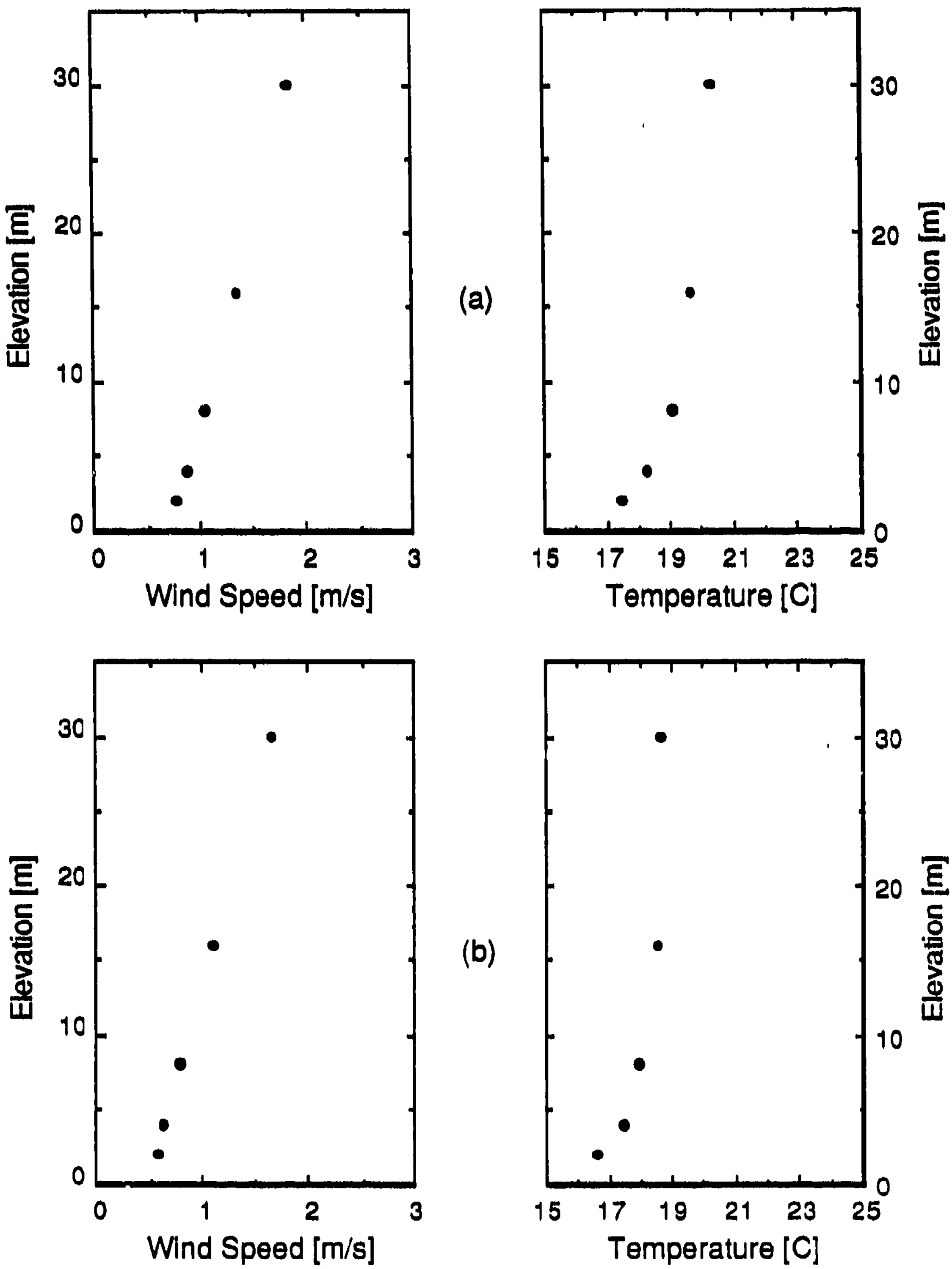


Figure 3.5 Vertical profiles of wind speed and temperature for (a) Test 1001871 and (b) Test 1002871.

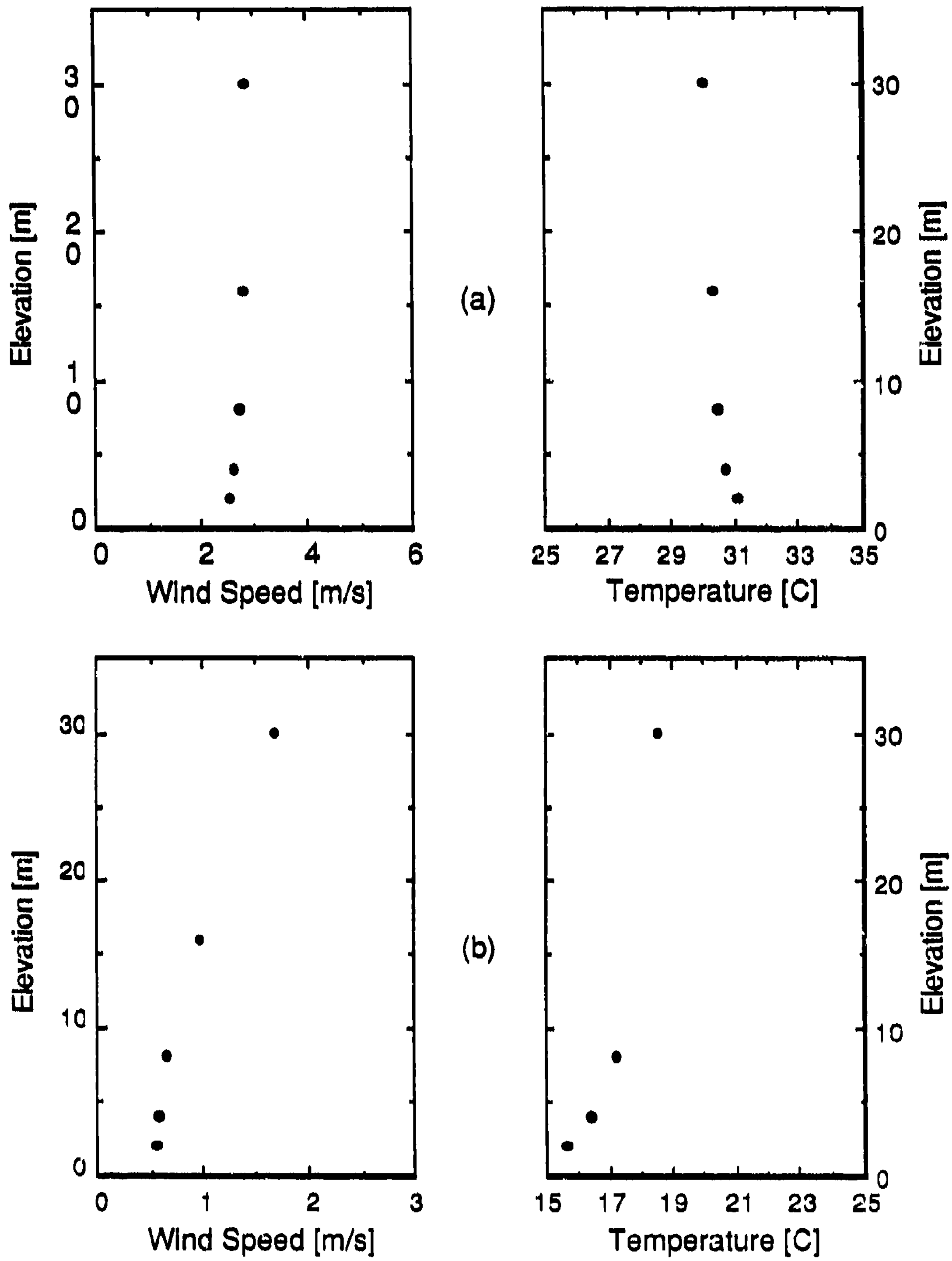


Figure 3.6 Vertical profiles of wind speed and temperature for (a) Test 1002872 and (b) Test 1003871.

3.2.3 Power Spectra

The power spectra of the velocity fluctuations provide valuable information about the structure of the atmospheric boundary layer. Specifically, analysis of spectra allows one to determine the scale of motions which most contribute to horizontal and vertical mixing. The spectra also allow the consistency of the data between the various measurement levels to be assessed and comparisons to be made with other studies of the atmospheric boundary layer.

Two alternative methods are available to compute the single-sided power spectrum. One method, which we call the "direct method" involves the direct computation of the autocorrelation function of the velocity fluctuations. The autocorrelation function is then integrated to obtain the spectra. A second method, which we call the "indirect method", relies on the use of Fast Fourier Transform techniques to decompose individual segments of the data into their sine and cosine components. The transformed data are then ensemble averaged to obtain the spectra. Because the individual data segments are not independent (and are, in fact, usually overlapping) a filtering function is applied to the data before the decomposition is made.

In order that we might be able to detect changes in the meteorological conditions during a single smoke release, we have elected to use the indirect method. This method generates a number of short-term spectra which can be analyzed for consistency. Of special concern are those tests which were conducted just before an expected transitional period.

We chose a interval length of 512 s and divided the data record over the course of a single trial into overlapping segments of this length. By this we mean that the first segment runs from 1 to 512 s, the second segment from 257 to 768 s, the third segment from 513 to 1024 s, and so on. Overlapping segments are known to reduce aliasing and distortion in the high frequency end of the spectral estimate. To account for the inherent dependency of these segments, we applied a Hanning weighting function to the data. Each of these segments was then decomposed into its sine and cosine components using the Fast Fourier Transform, and the resulting decompositions were ensemble averaged to obtain the raw spectra. These raw spectra were then normalized by the ensemble average of the segment variances and smoothed by summing the spectrum over specific frequency intervals and assigning the net result to the mid-point of the interval. The intervals were chosen to keep $\Delta n/n$ roughly constant, where Δn and n are the width and midpoint of the interval, respectively.

This method does not provide a convenient mechanism for handling bad and missing data. Since the number of such data was quite small, we elected to repair the data records by interpolating replacement values for the bad data. These few replacements values were only used for computing the spectra and do not affect the other results generated from the 1-s measurements.

The frequency-weighted, single-sided power spectra for the fluctuating components of wind velocity are presented in Figs. 3.7 – 3.18. For each figure, we have (a) $S_{uu}(n)$, the spectrum of the velocity fluctuations in the direction of the mean wind, (b) $S_{vv}(n)$, the spectrum of the velocity fluctuations in the direction normal to the mean wind, (c) $S_{ww}(n)$, the spectrum of the velocity fluctuations in the vertical direction and (d) the spectral ratios $S_{vv}(n) / S_{uu}(n)$ and $S_{ww}(n) / S_{uu}(n)$. The spectral ratios assist in determining the isotropy of the turbulence.

As a group, the unstable daytime tests give the most coherent spectra with little variation between the levels for the mean-wind and cross-wind components. For the vertical spectra, the upper levels have a greater fraction of energy in the low frequency range. This indicates that the scale of the turbulent motion increases with height as may be logically expected. Moreover, most of the unstable cases show a fair degree of isotropy in the horizontal plane which is consistent with the results of studies carried out over flat terrain. This is perhaps because the micrometeorological tower is located in a relatively flat, open area on the valley floor.

The spectra obtained for the stable nighttime and early morning conditions are much more disorganized. The individual spectra show some form but great variations are present between the different levels of the tower with a general loss of energy at the lower levels. Much of this can be attributed to the light and variable winds during these tests. There is an almost complete breakdown of the wind field near the ground. Many of the stable spectra show unusual behavior on the high frequency end. This is especially prevalent in the vertical velocity spectra. The cause of these "tails" has been thoroughly investigated and two possible sources have been ruled out. The first suspected cause was momentary periods of strong intermittent turbulence which would occur one or two times during a test period. These events were characterized by large vertical velocities and could be easily identified in a time trace. A filter was implemented to removed these large variations, but it had a negligible effect on the spectra. It was also thought that these tails could be the result of discretization errors, but this hypothesis was also disproved. The tails cannot be easily explained away and thus must be considered an integral part of the field data.

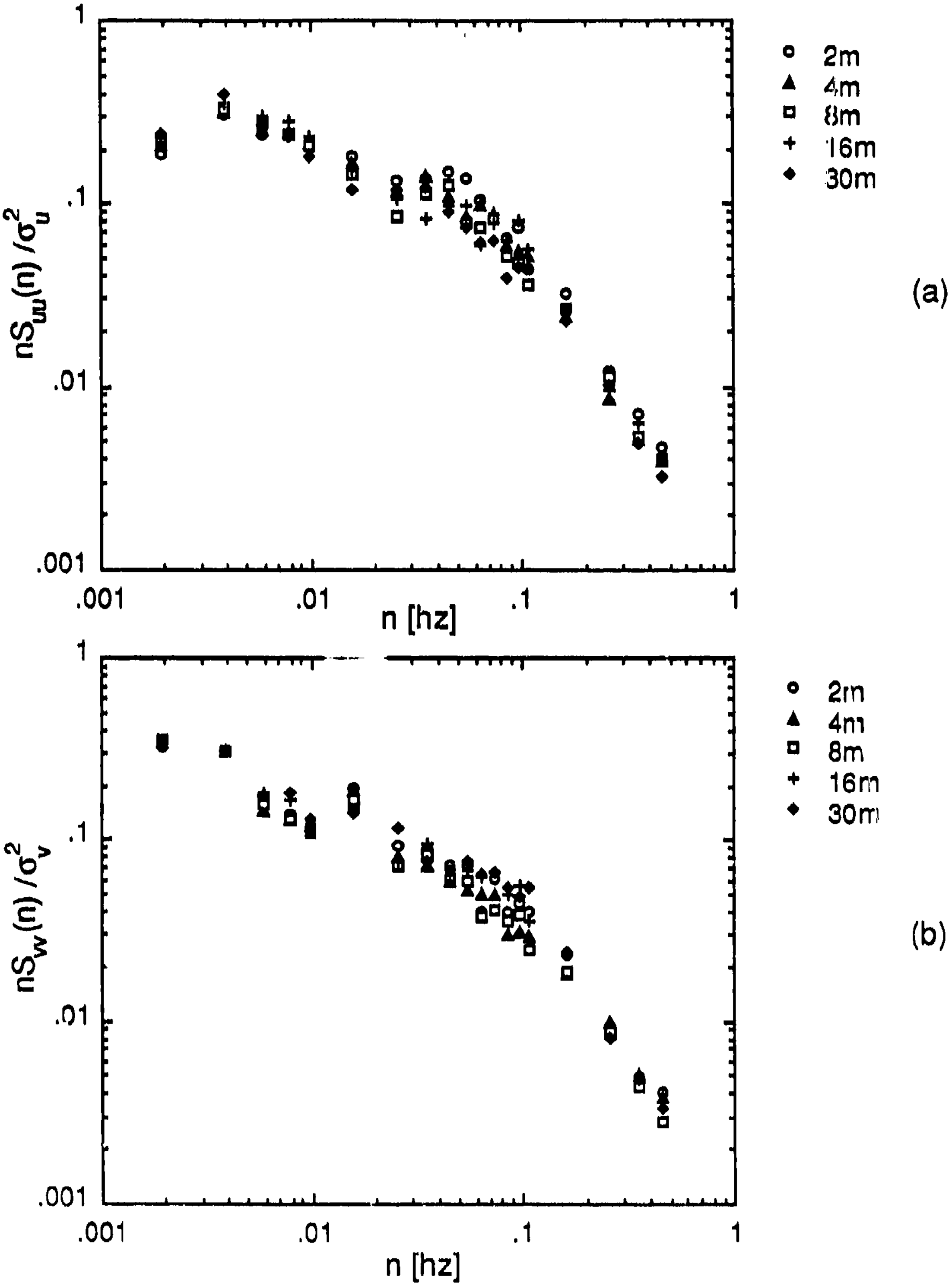


Figure 3.7 Spectra for Test 0921871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 14:30 to 15:00. The unstable release point was used.

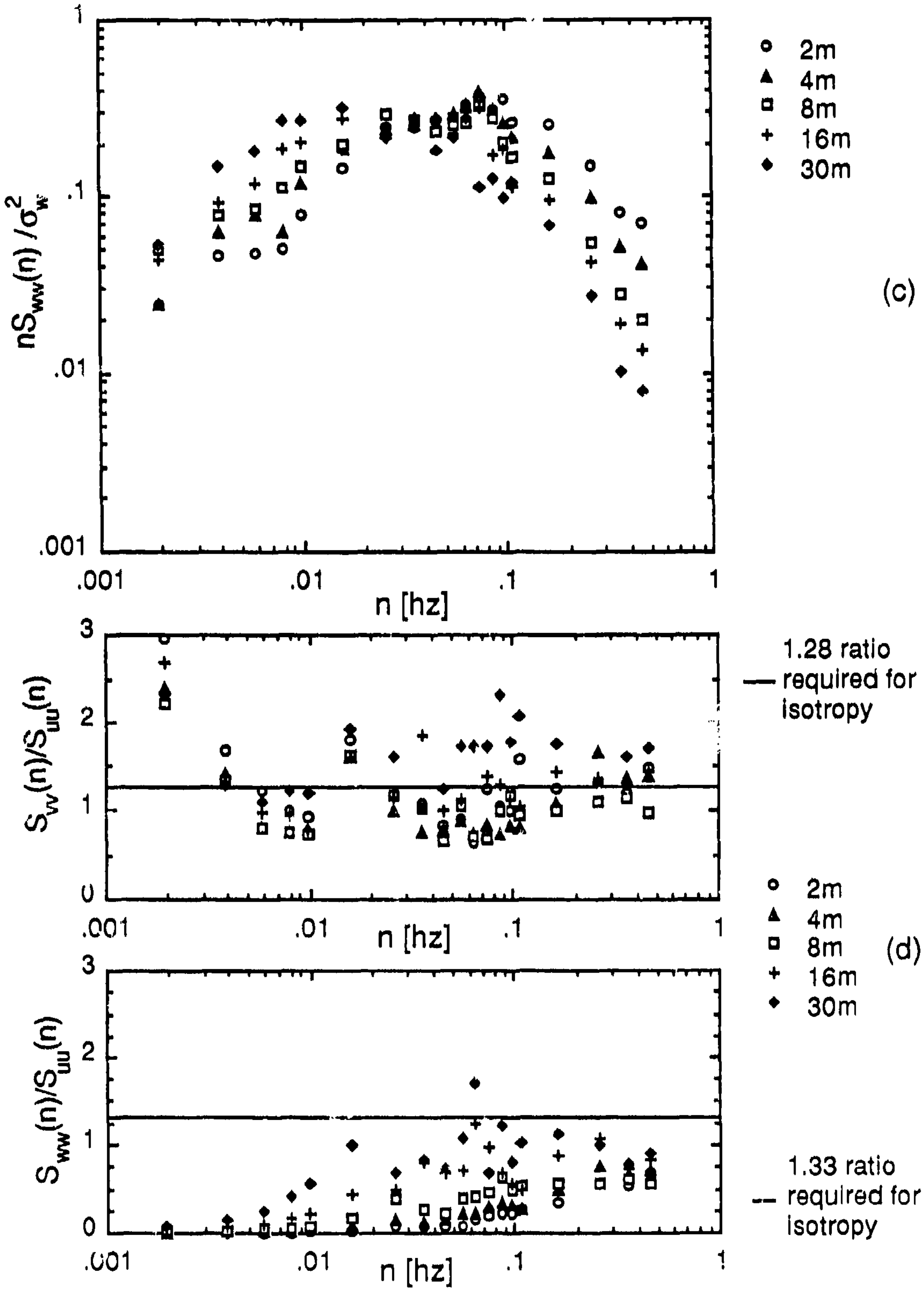


Figure 3.7 Spectra for Test 0921871 (c) vertical component and (d) spectral ratios. Smoke was released from 14:30 to 15:00. The unstable release point was used.

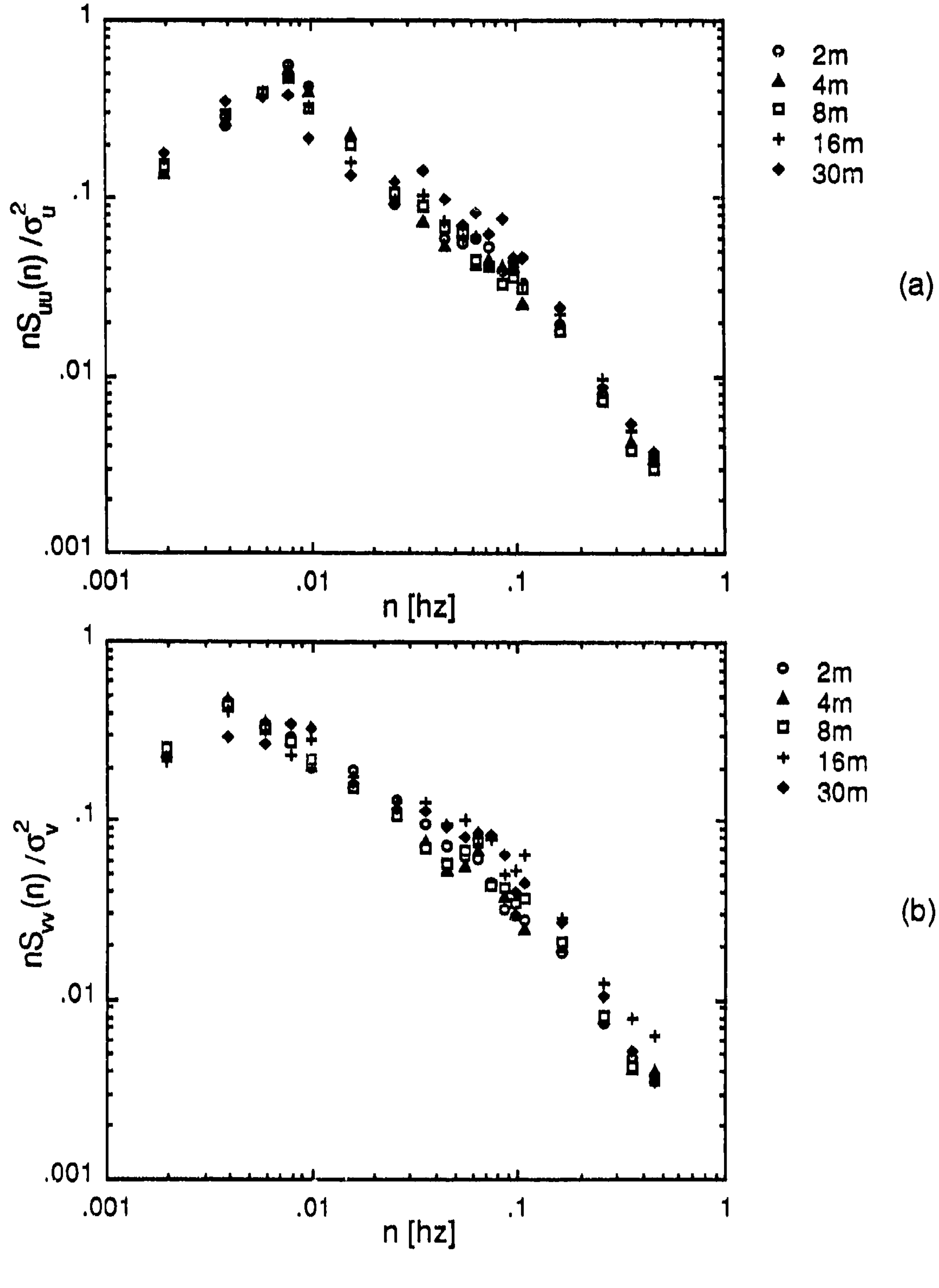


Figure 3.8 Spectra for Test 0923871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 14:00 to 14:50. The smoke moved off the grid at 14:50. The unstable release point was used.

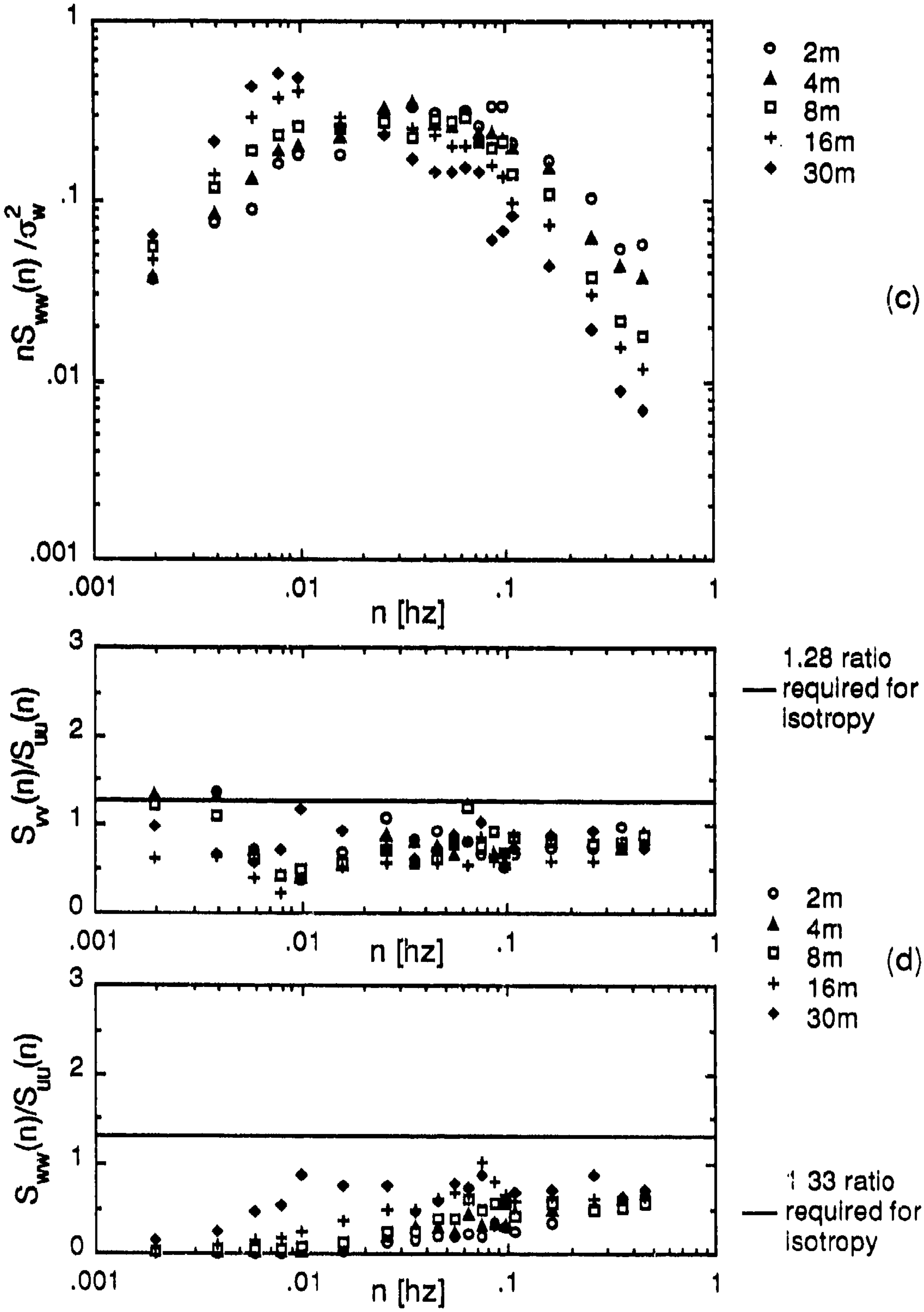


Figure 3.8 Spectra for Test 0923871 (c) vertical component and (d) spectral ratios. Smoke was released from 14:00 to 14:50. The smoke moved off the grid at 14:50. The unstable release point was used.

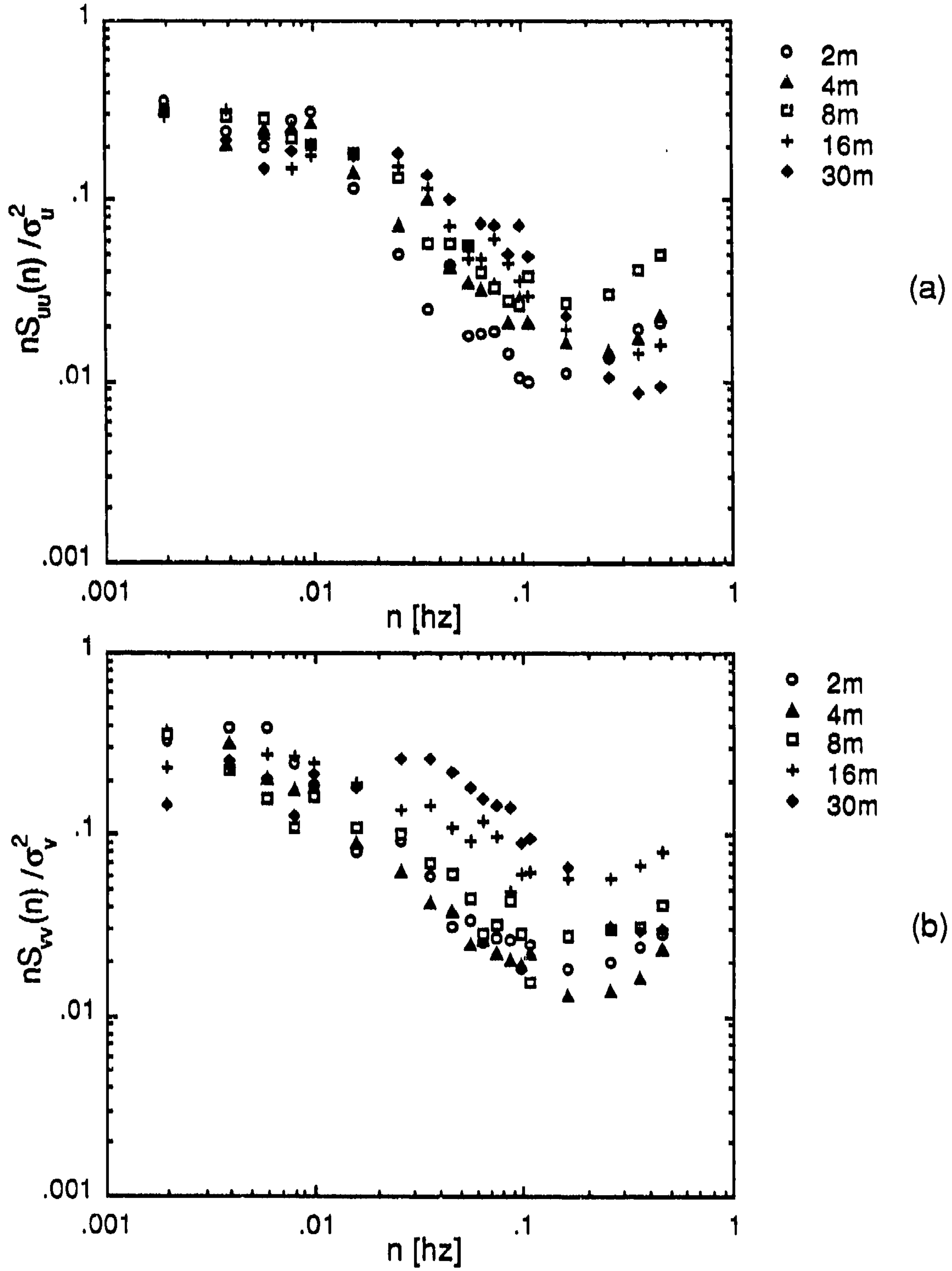


Figure 3.9 Spectra for Test 0925871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 00:18 to 01:03. The stable release point was used.

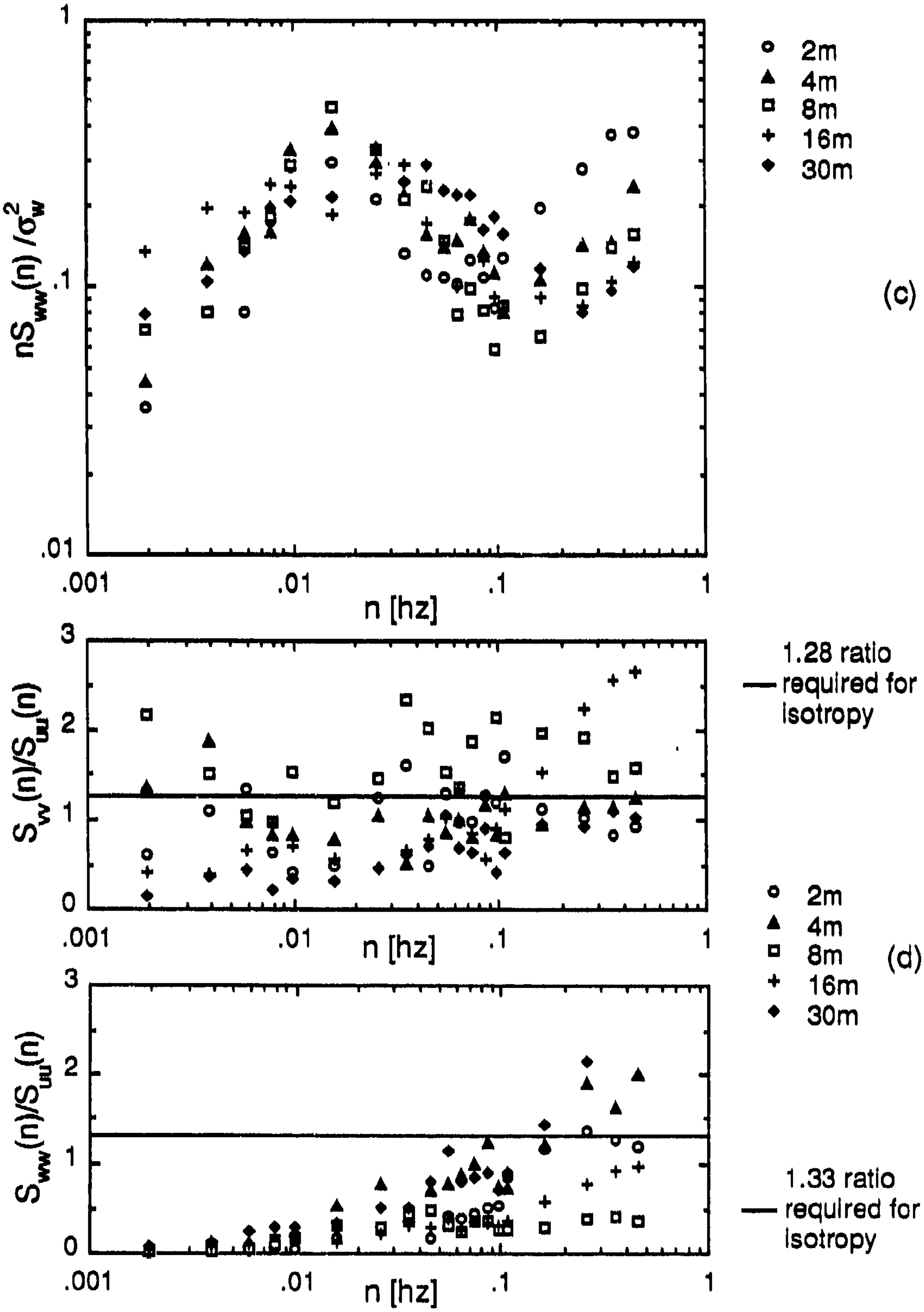
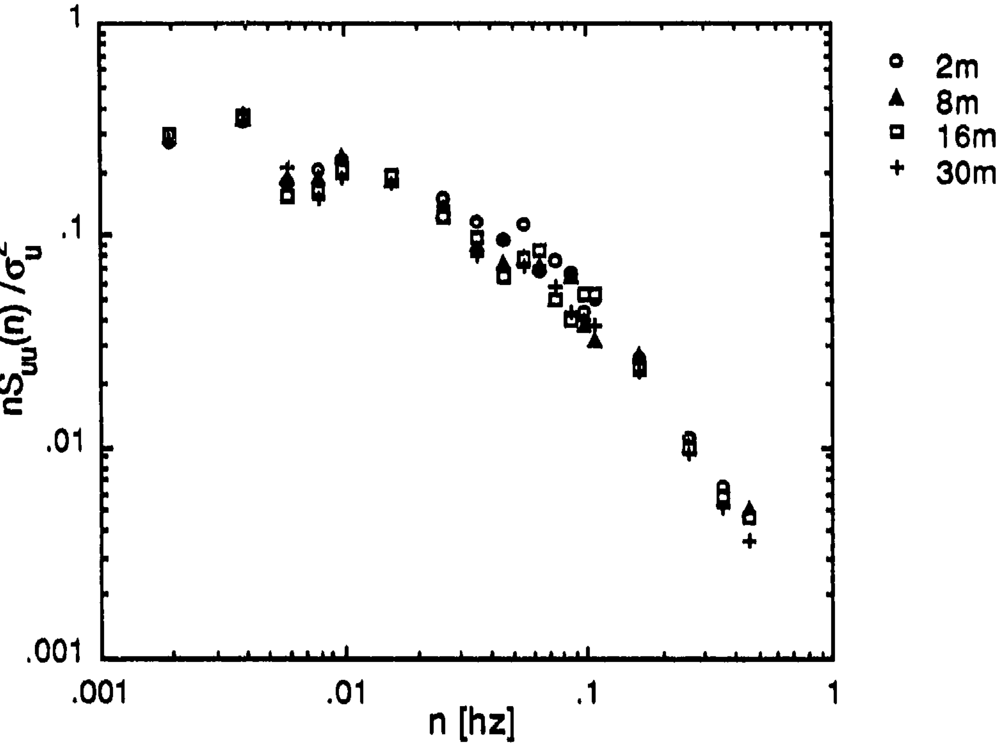
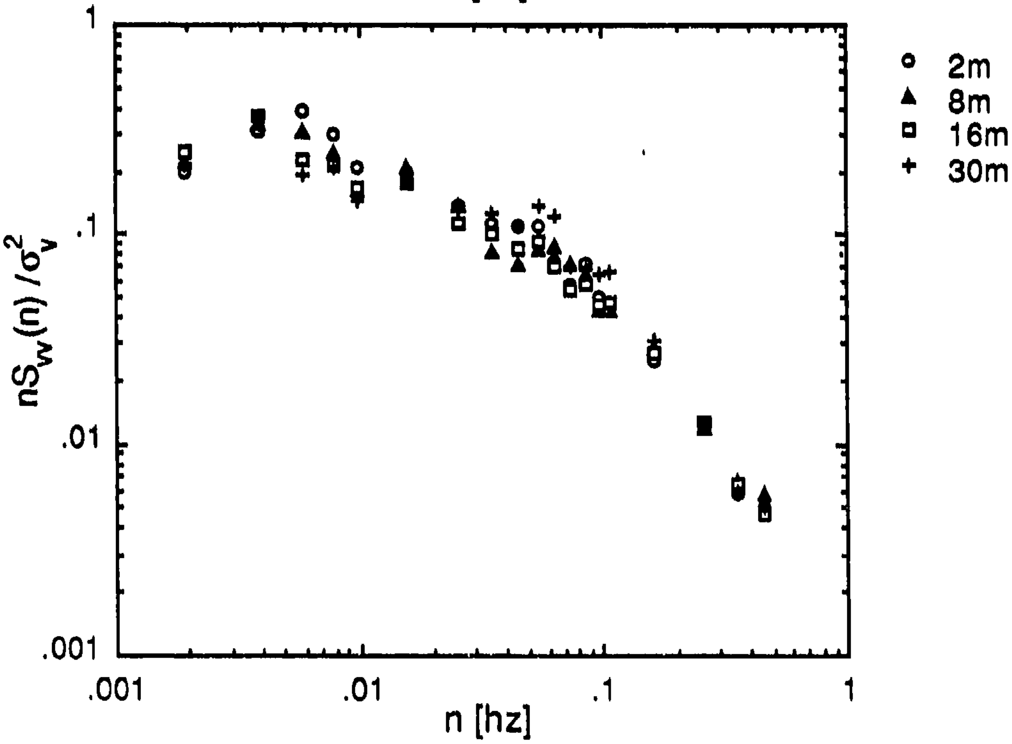


Figure 3.9 Spectra for Test 0925871 (c) vertical component and (d) spectral ratios. Smoke was released from 00:18 to 01:03. The stable release point was used.



(a)



(b)

Figure 3.10 Spectra for Test 0926871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 12:00 to 13:07. The unstable release point was used.

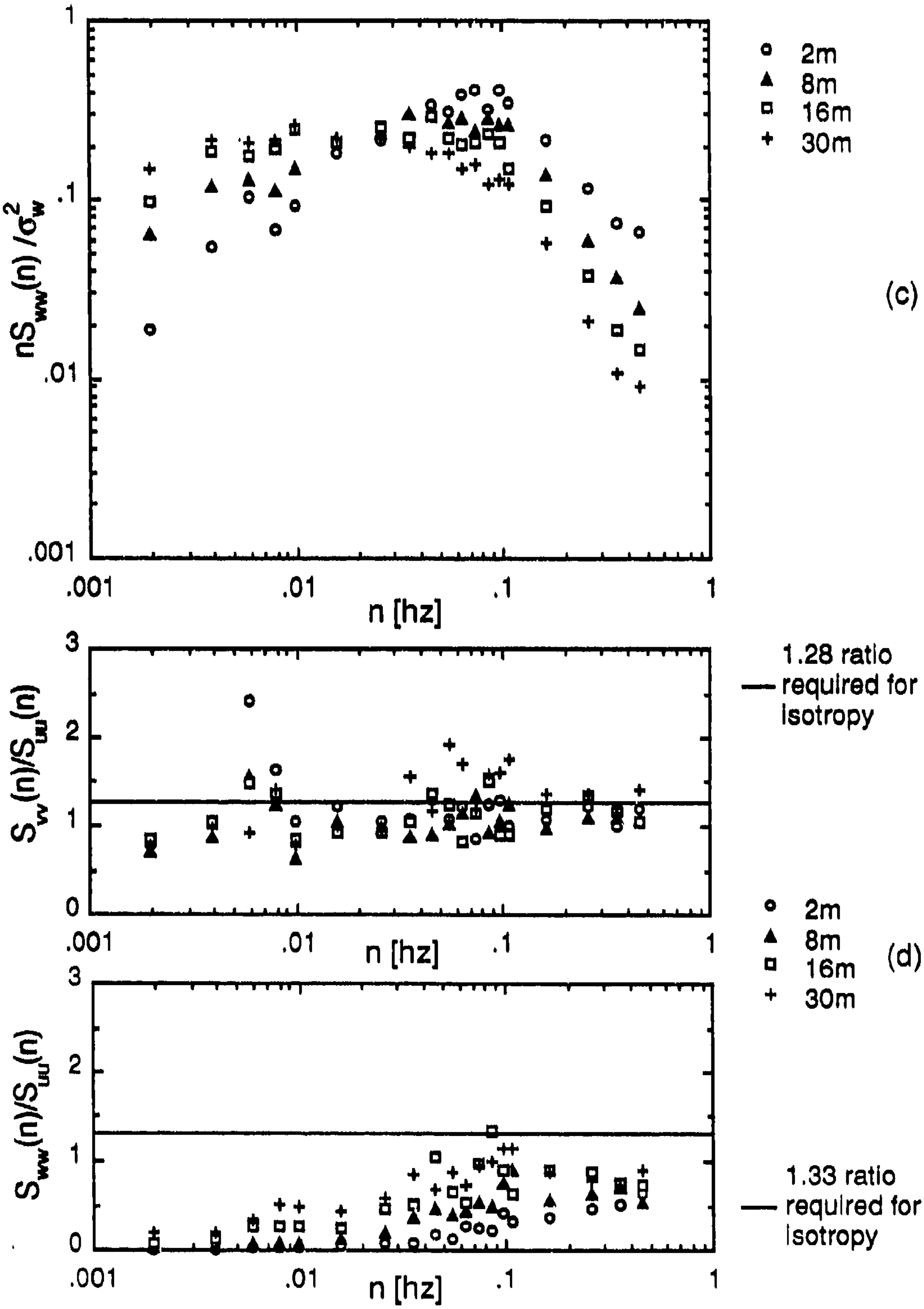


Figure 3.10 Spectra for Test 0926871 (c) vertical component and (d) spectral ratios. Smoke was released from 12:00 to 13:07. The unstable release point was used.

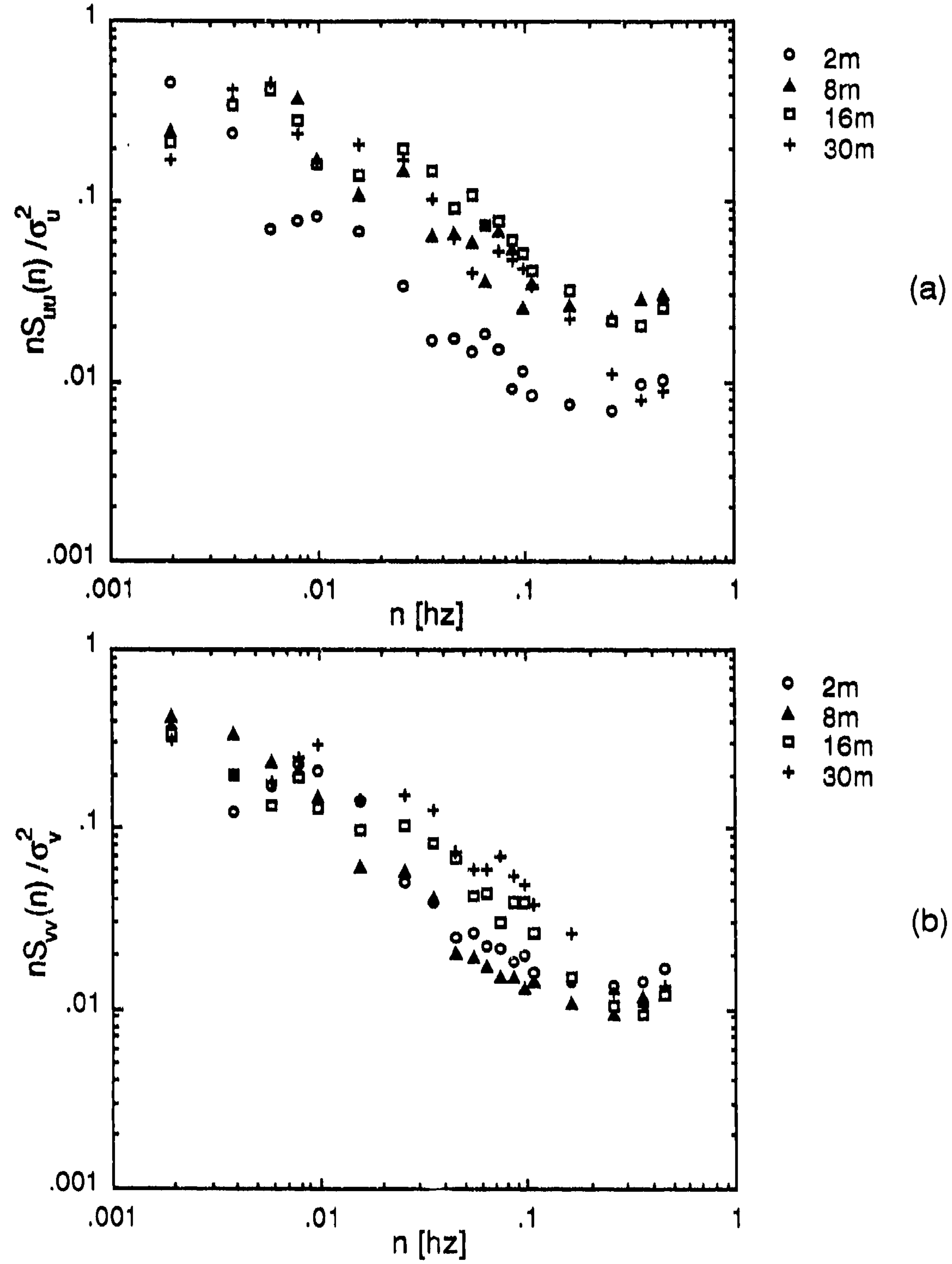
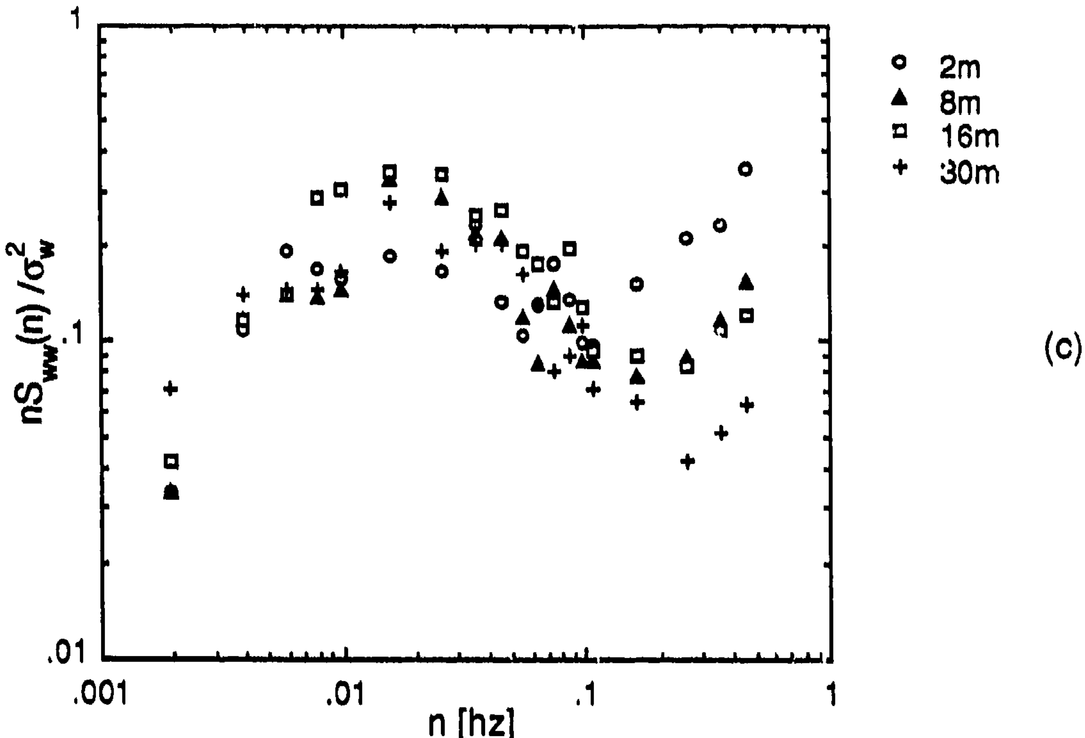


Figure 3.11 Spectra for Test 0927871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 03:19 to 03:39. The stable release point was used.



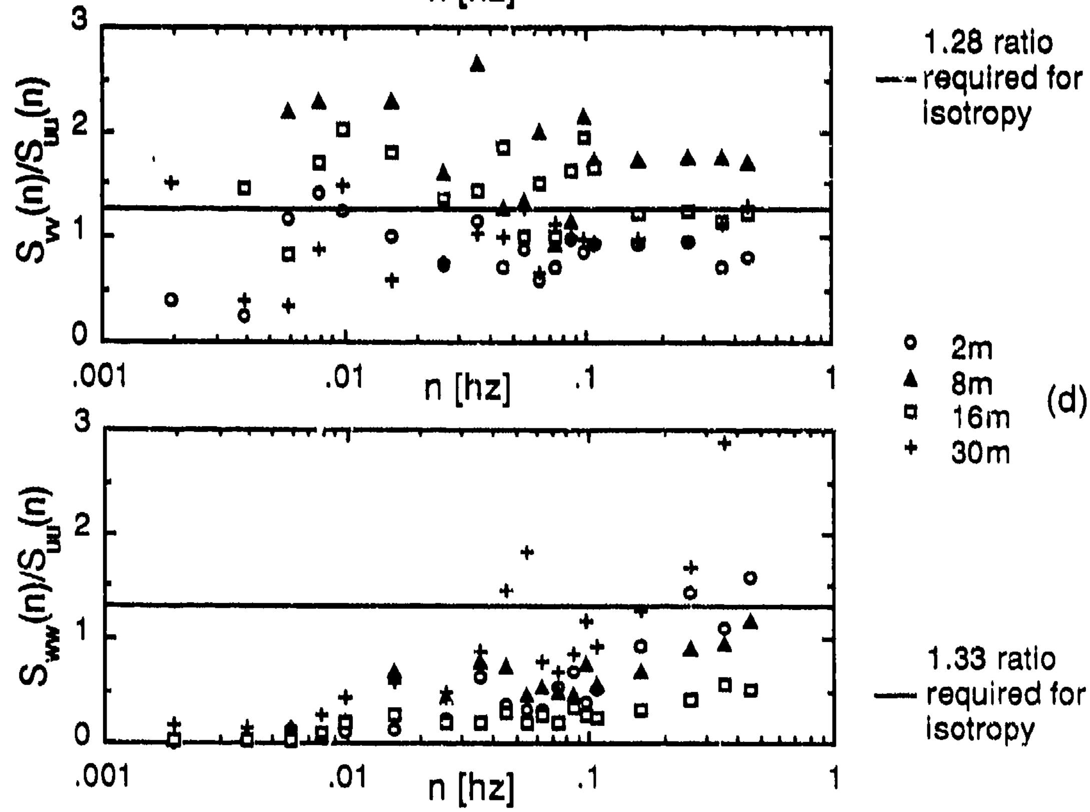


Figure 3.11 Spectra for Test 0927871 (c) vertical component and (d) spectral ratios. Smoke was released from 03:19 to 03:39. The stable release point was used.

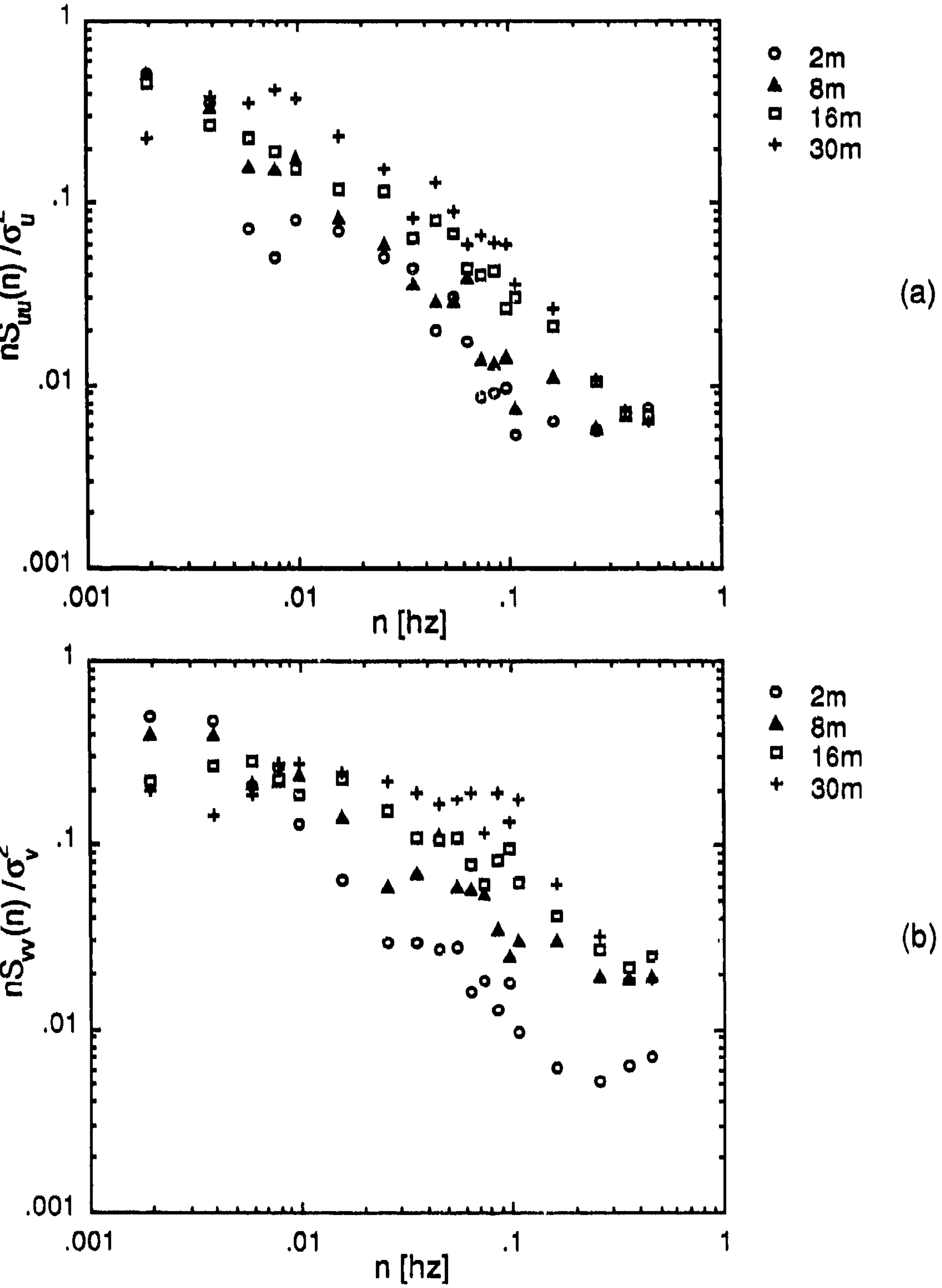


Figure 3.12 Spectra for Test 0927872 (a) mean-wind component and (b) cross-wind component. Smoke was released from 06:44 to 06:54. The stable release point was used.

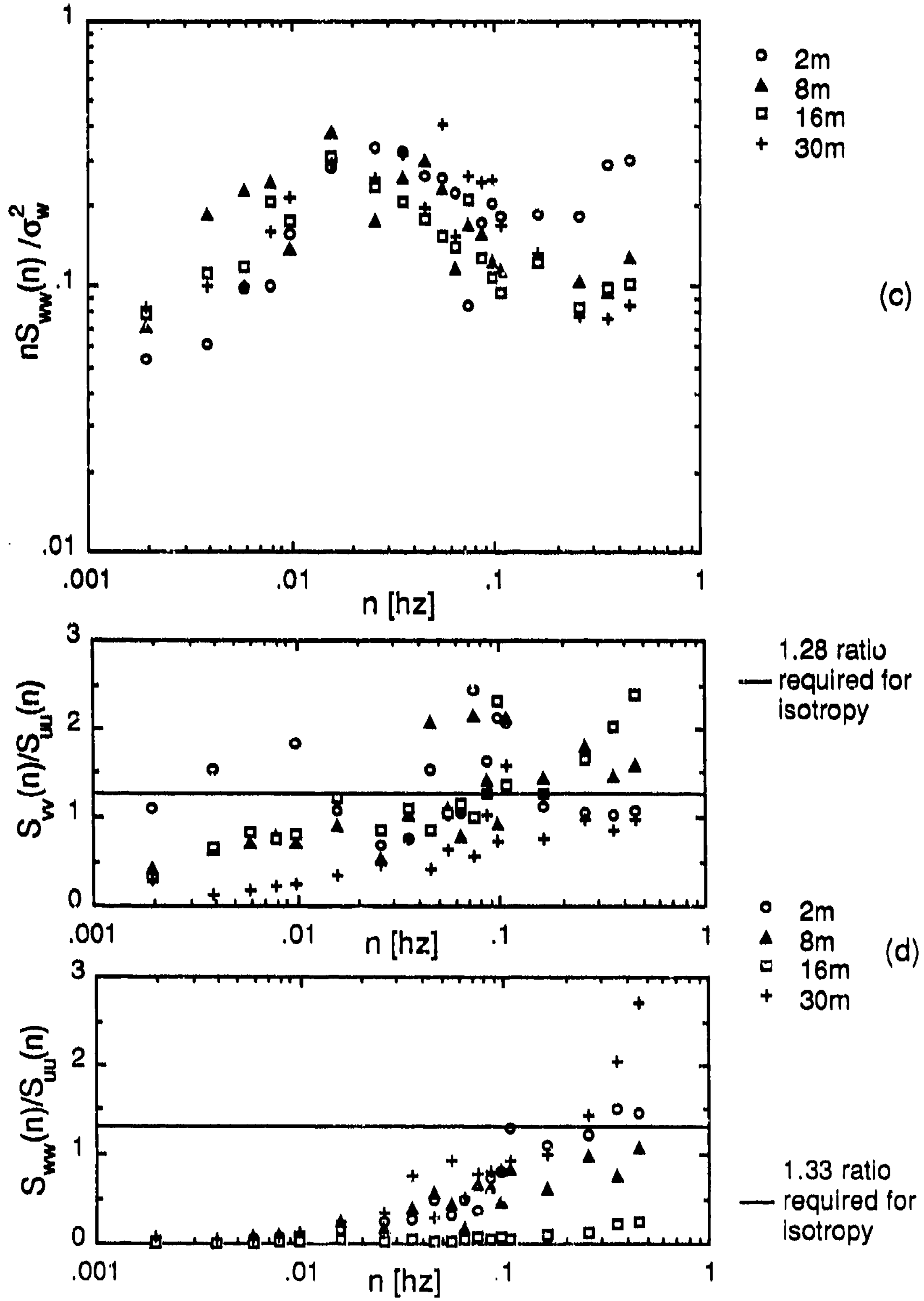


Figure 3.12 Spectra for Test 0927872 (c) vertical component and (d) spectral ratios. Smoke was released from 06:44 to 06:54. The stable release point was used.

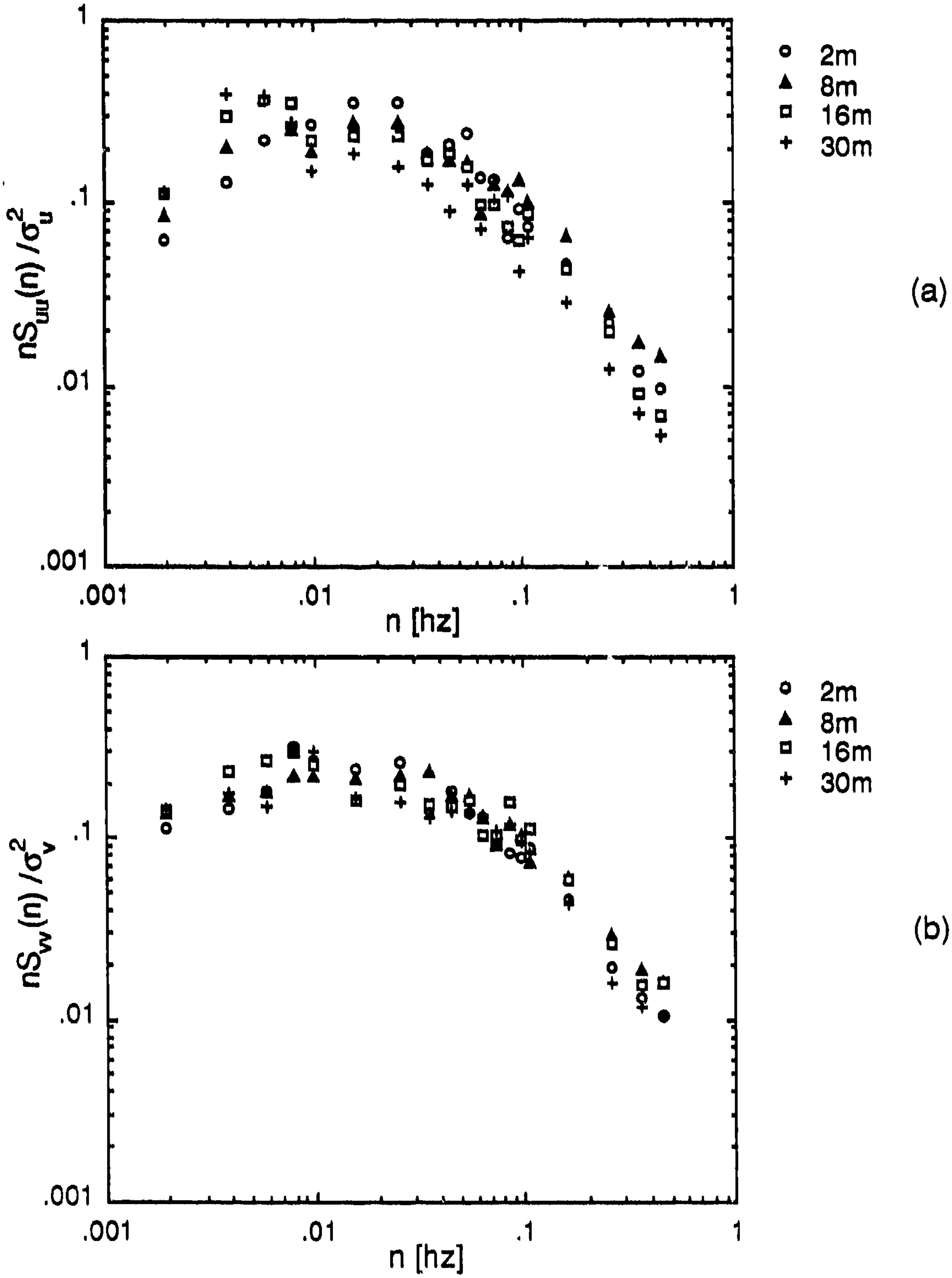


Figure 3.13 Spectra for Test 0928871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 10:29 to 10:54. The unstable release point was used.

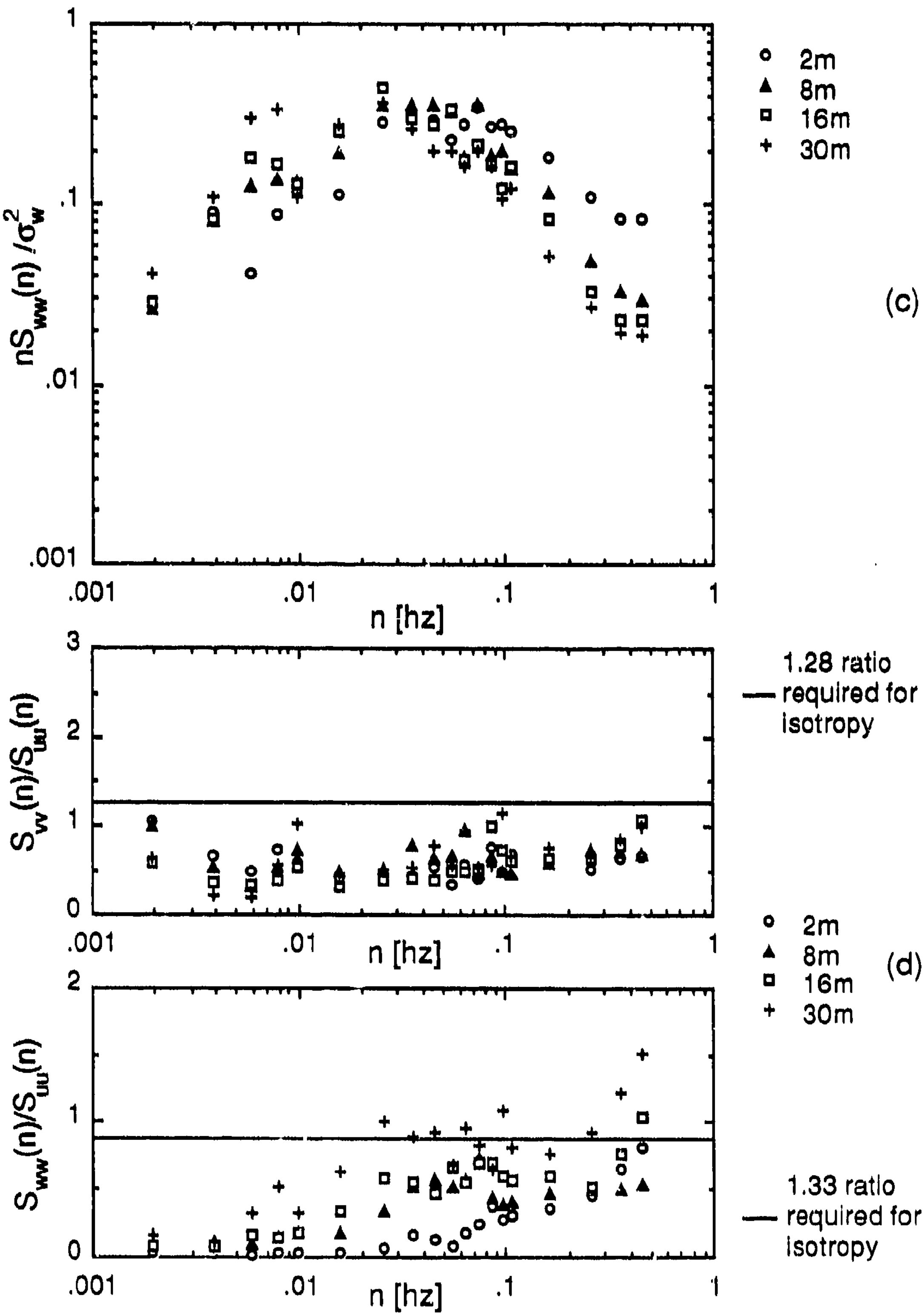


Figure 3.13 Spectra for Test 0928871 (c) vertical component and (d) spectral ratios. Smoke was released from 10:29 to 10:54. The unstable release point was used.

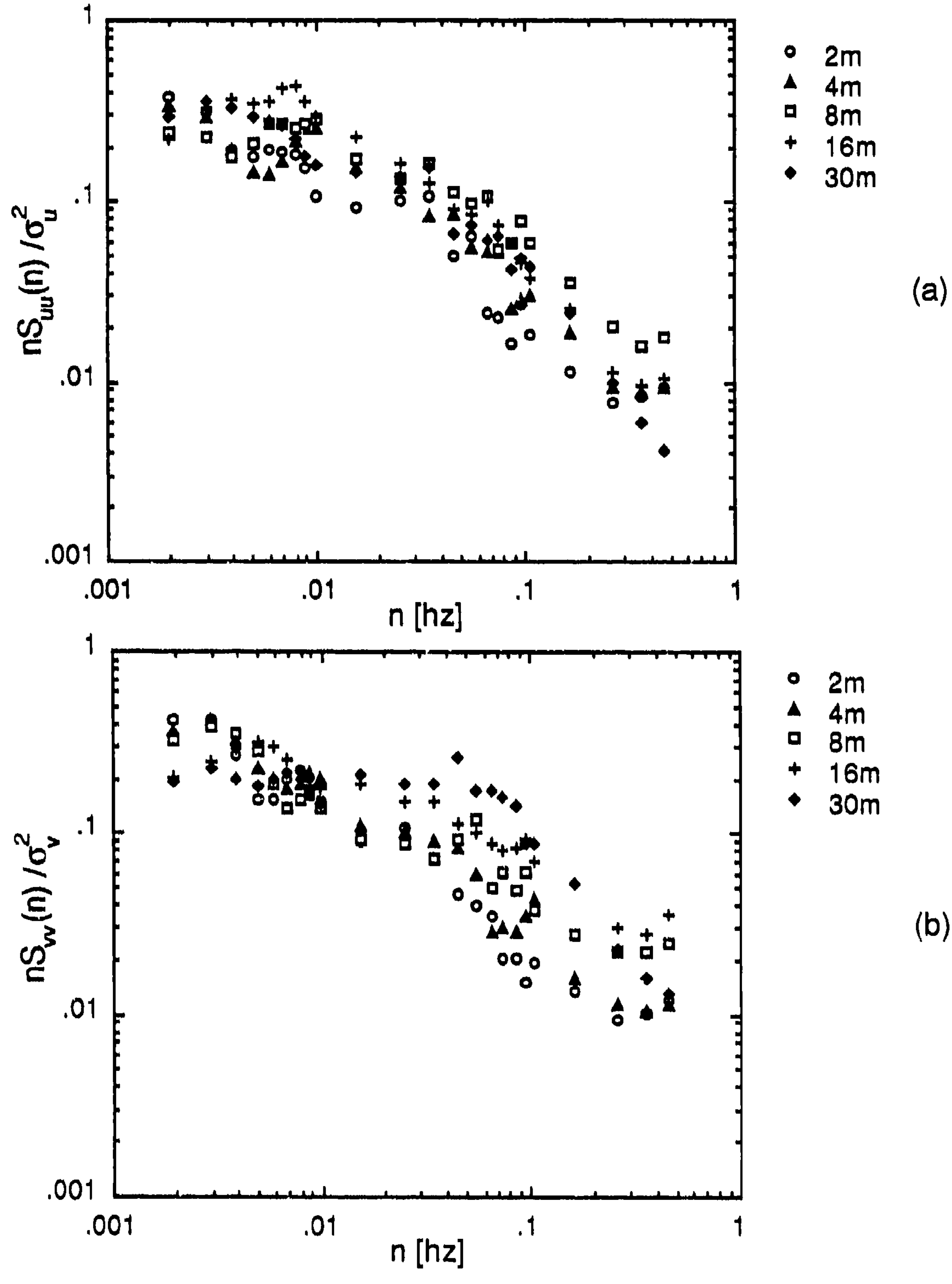


Figure 3.14 Spectra for Test 0930871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 06:48 to 07:28. The stable release point was used.

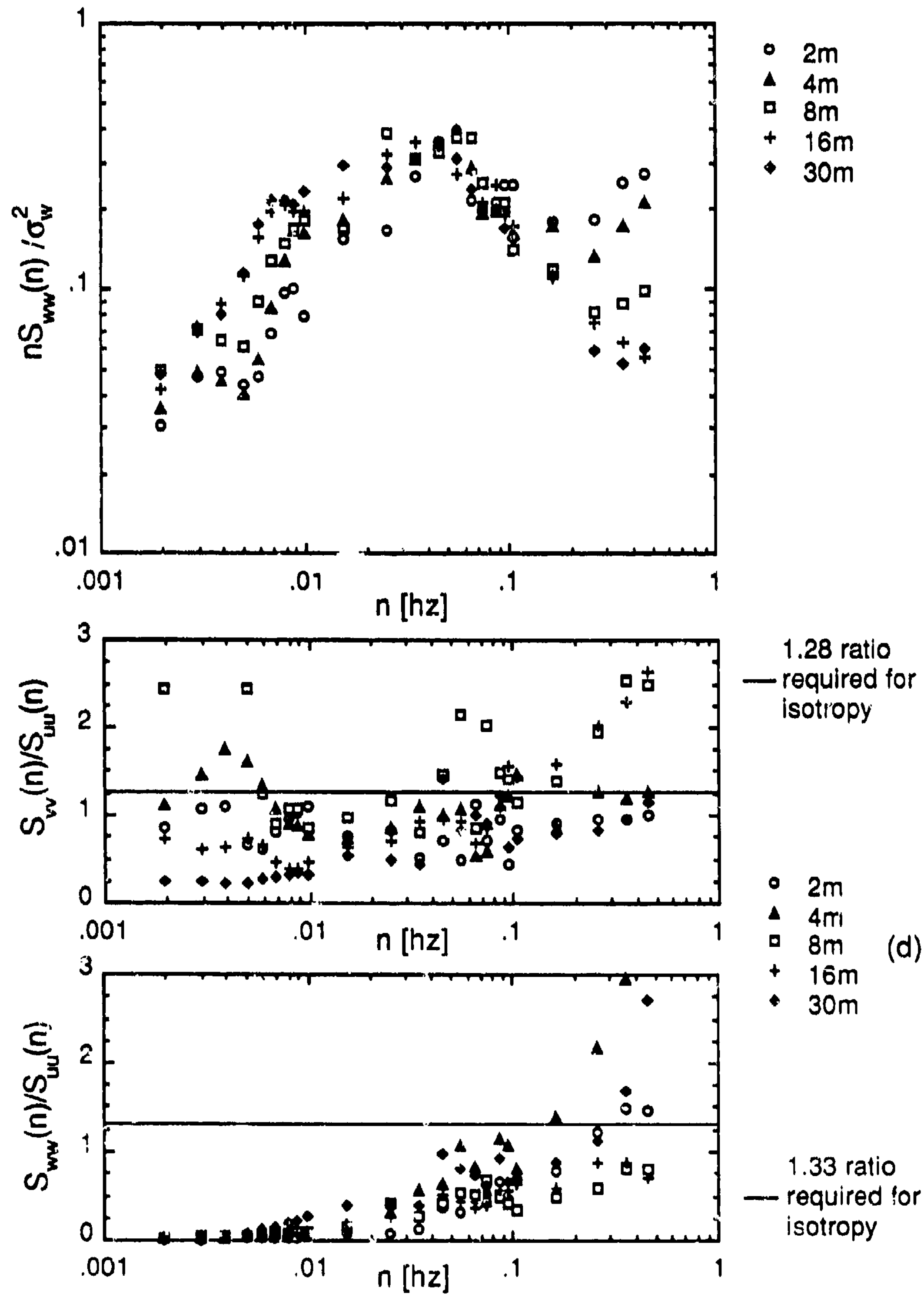


Figure 3.14 Spectra for Test 0930871 (c) vertical component and (d) spectral ratios. Smoke was released from 06:48 to 07:28. The stable release point was used.

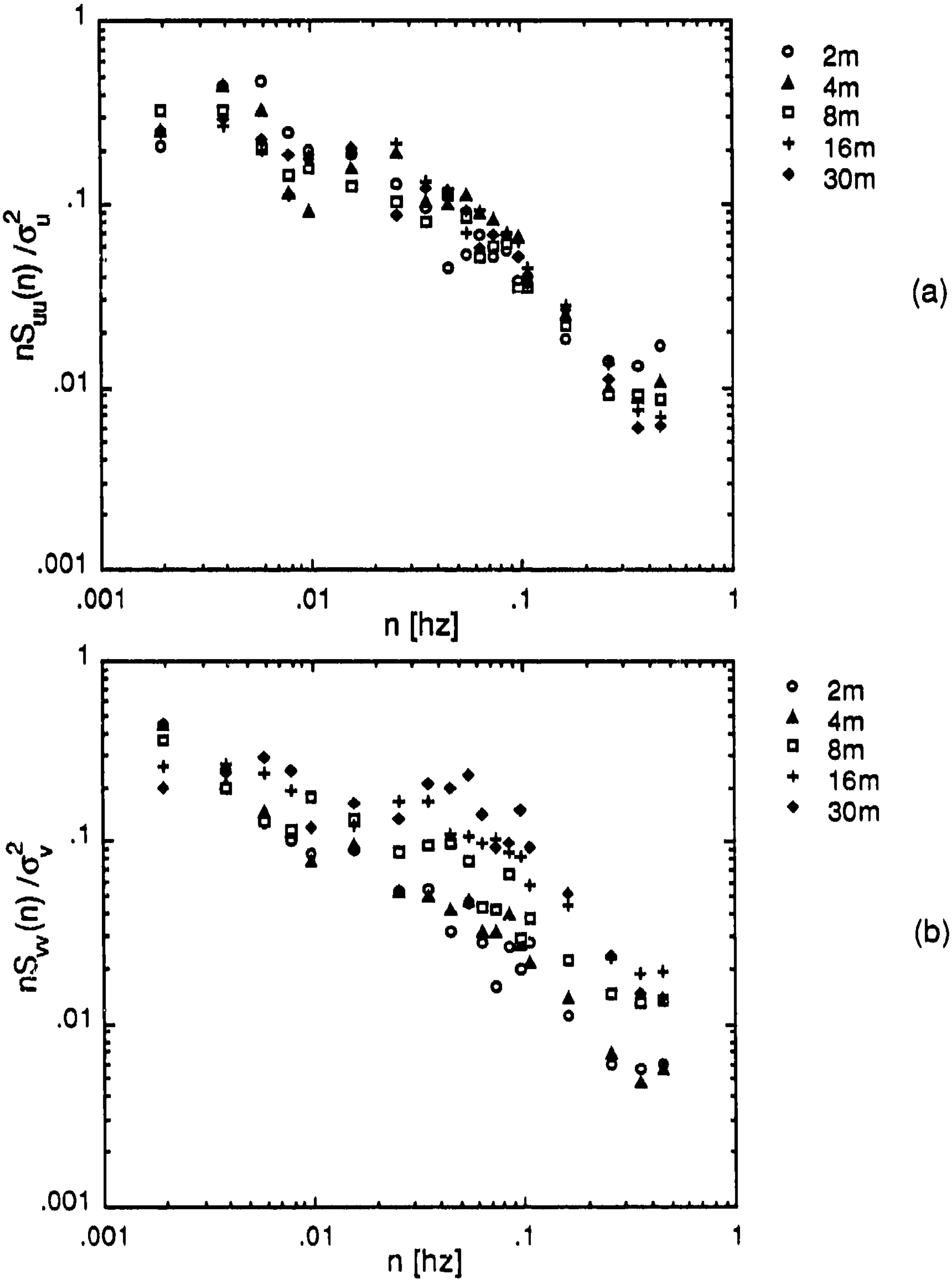


Figure 3.15 Spectra for Test 1001871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 06:52 to 07:32. The stable release point was used.

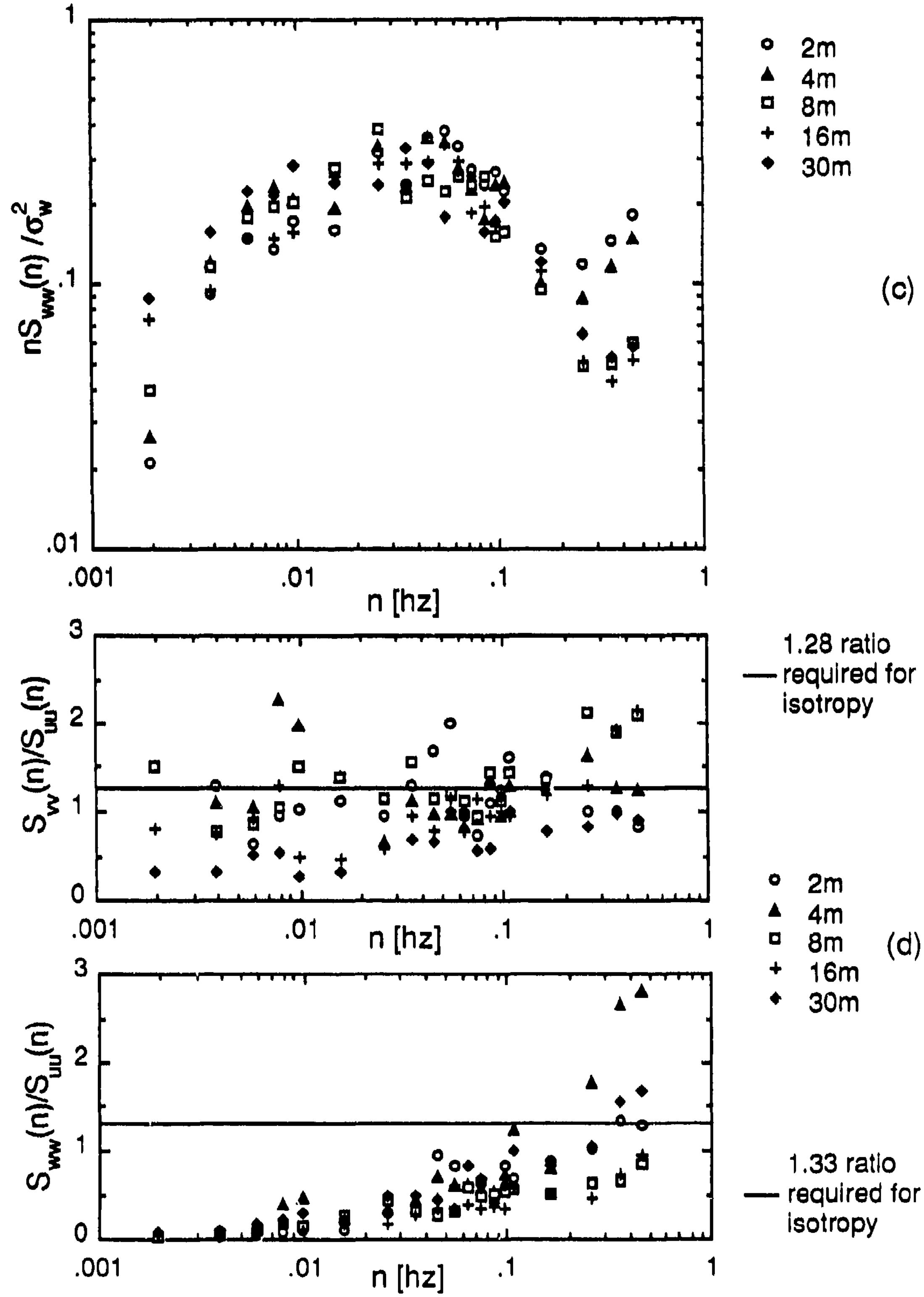


Figure 3.15 Spectra for Test 1001871 (c) vertical component and (d) spectral ratios. Smoke was released from 06:52 to 07:32. The stable release point was used.

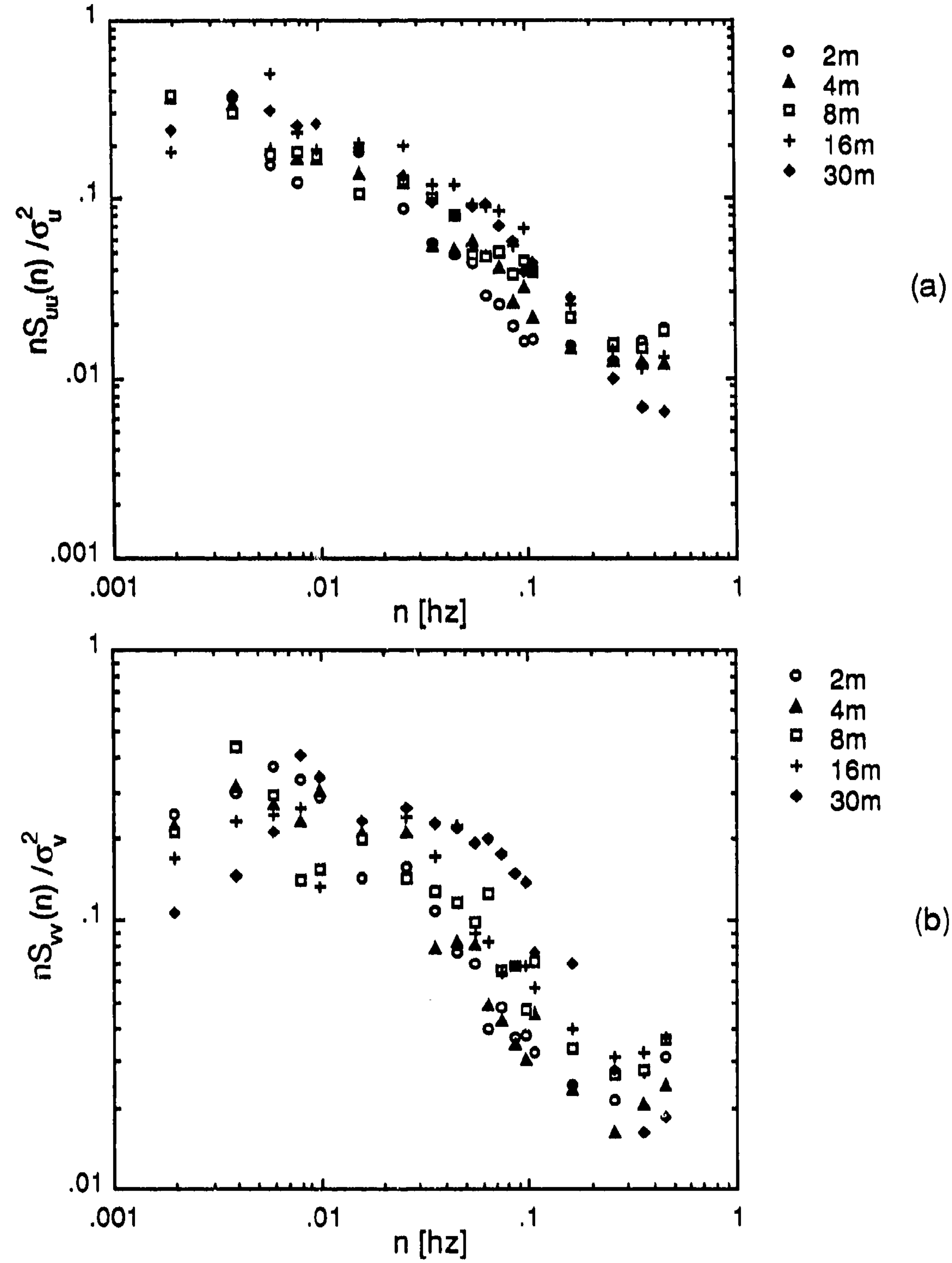


Figure 3.16 Spectra for Test 1002871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 07:17 to 07:47. The stable release point was used.

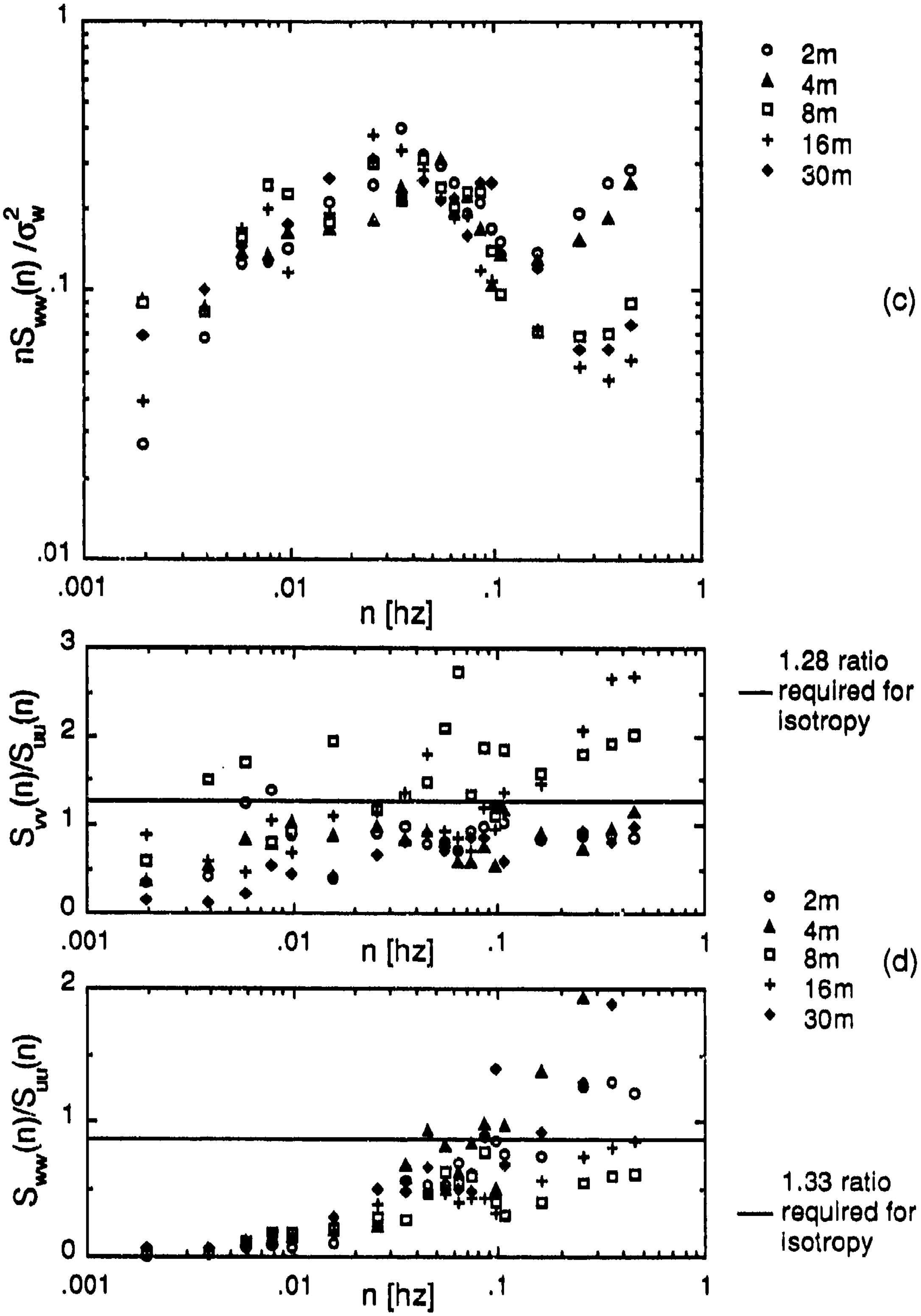


Figure 3.16 Spectra for Test 1002871 (c) vertical component and (d) spectral ratios. Smoke was released from 07:17 to 07:47. The stable release point was used.

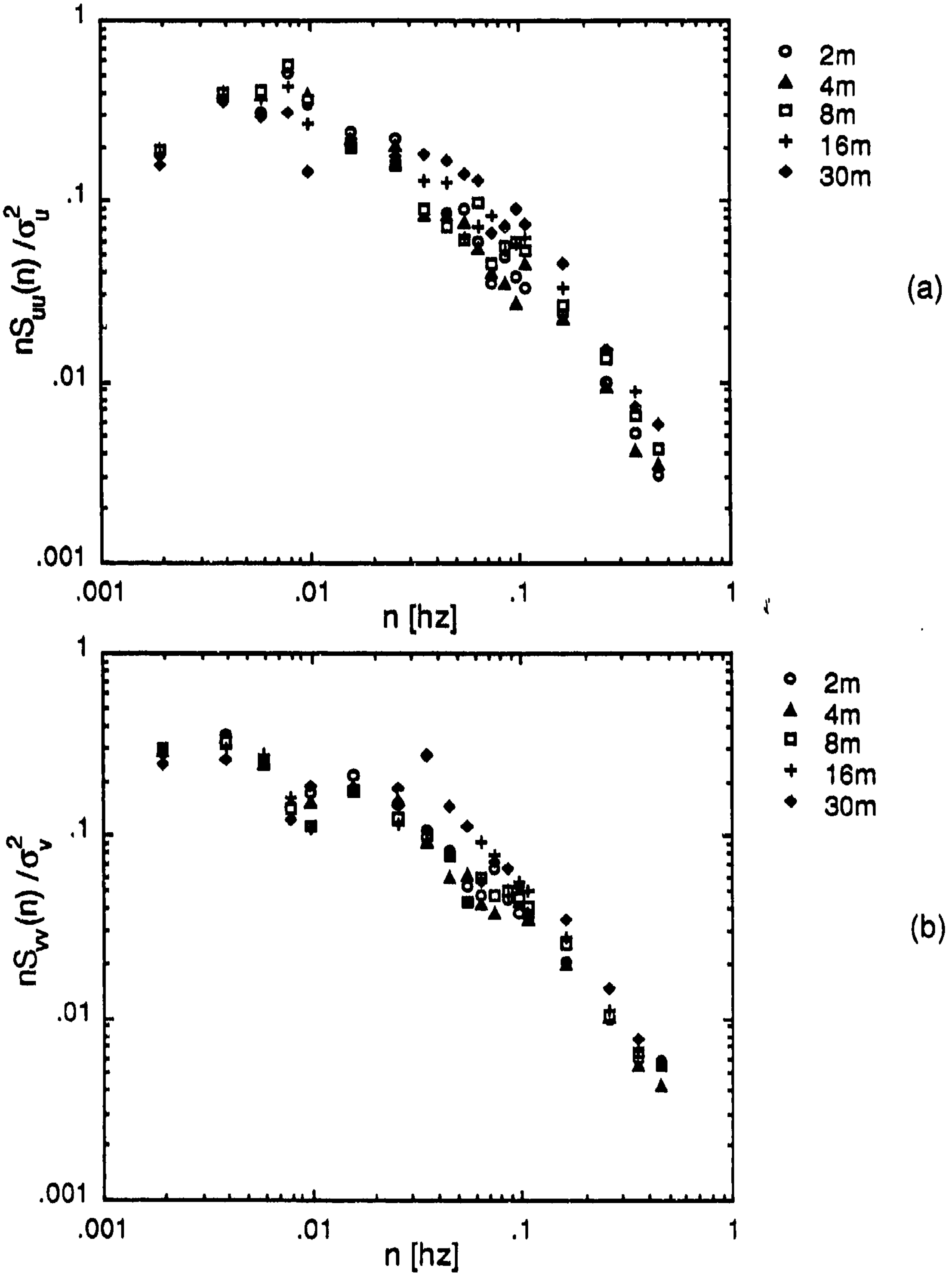


Figure 3.17 Spectra for Test 1002872 (a) mean-wind component and (b) cross-wind component. Smoke was released from 12:16 to 12:34. The unstable release point was used.

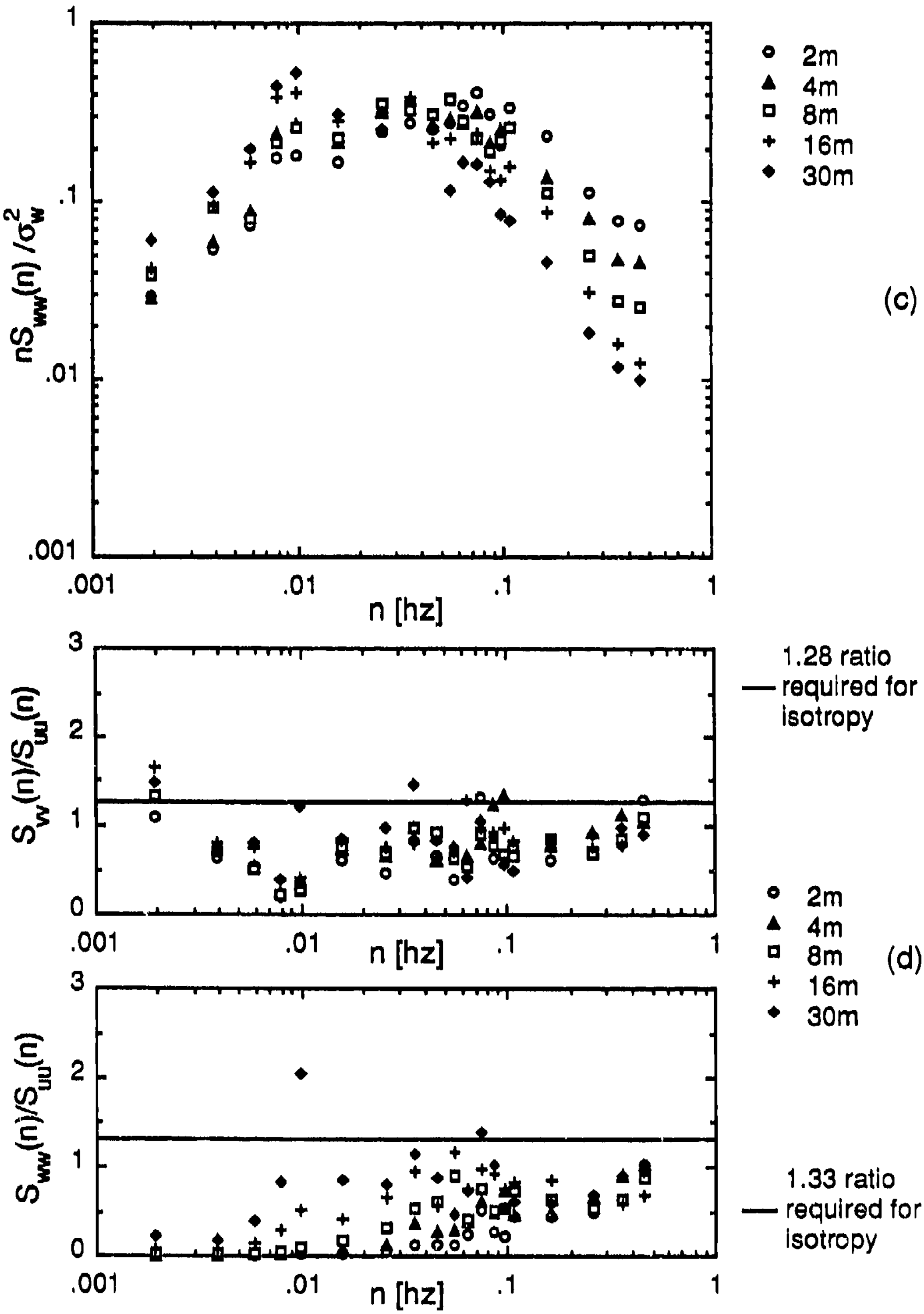


Figure 3.17 Spectra for Test 1002872 (c) vertical component and (d) spectral ratios. Smoke was released from 12:16 to 12:34. The unstable release point was used.

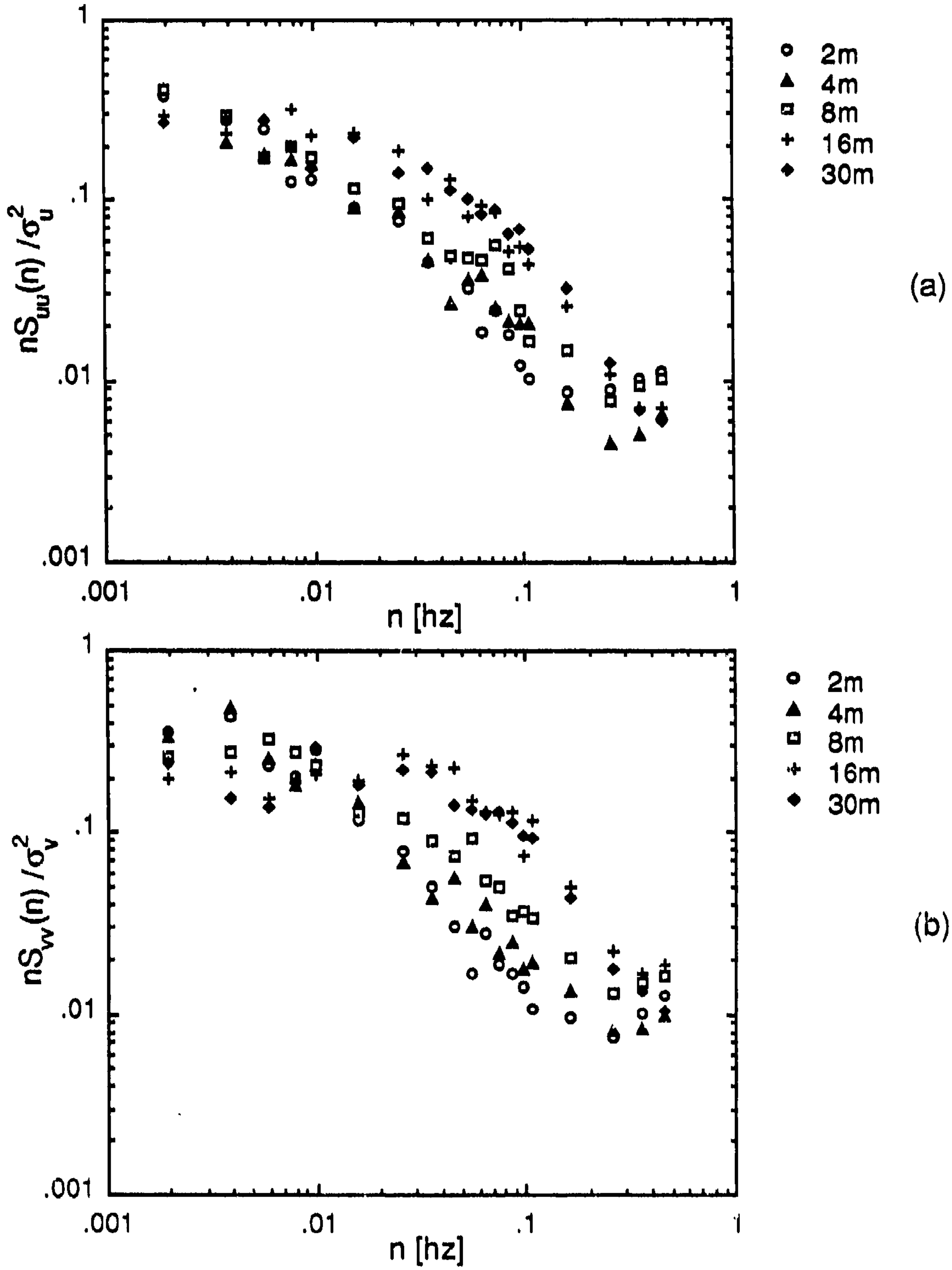


Figure 3.18 Spectra for Test 1003871 (a) mean-wind component and (b) cross-wind component. Smoke was released from 06:56 to 07:27. The stable release point was used.

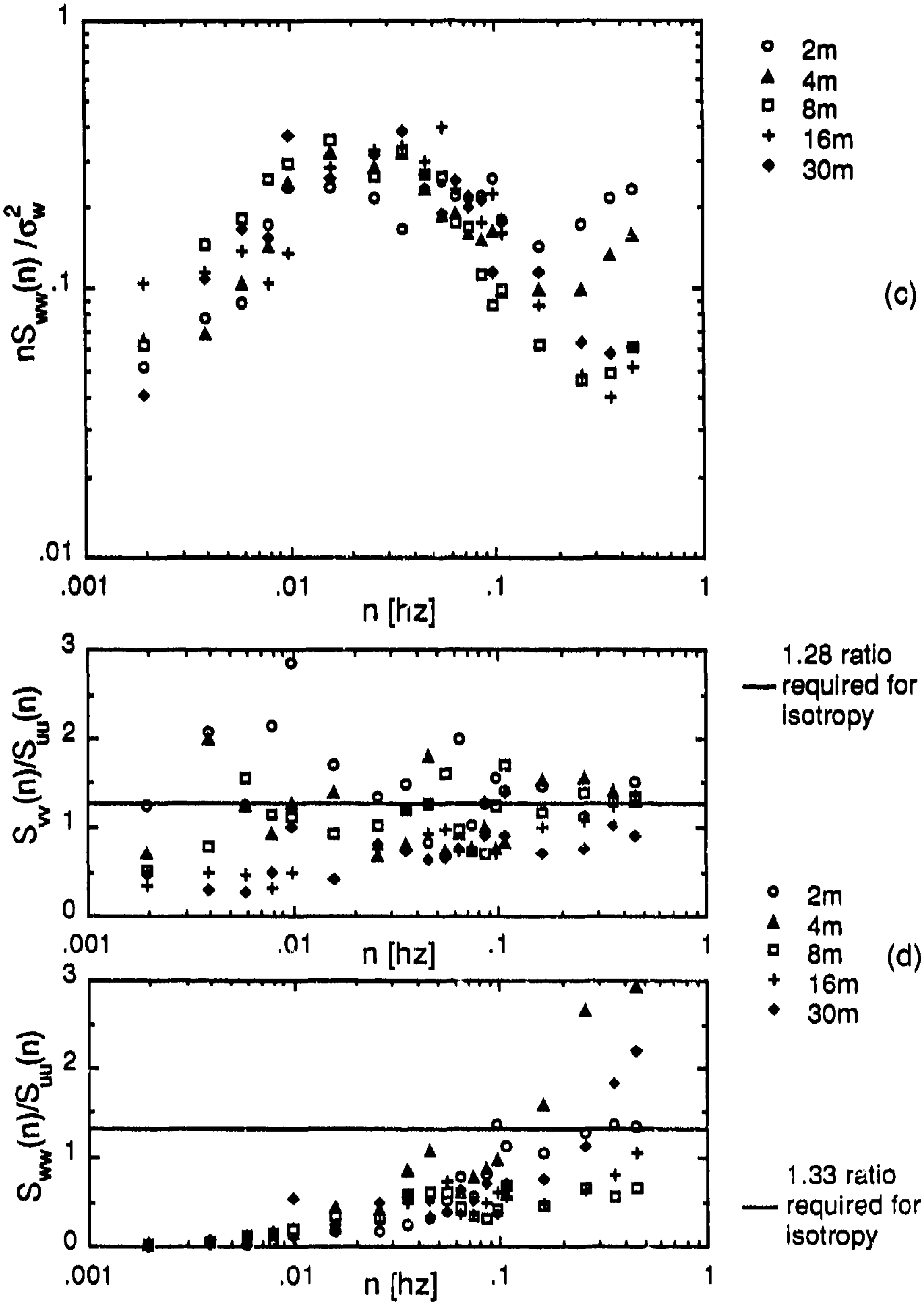


Figure 3.18 Spectra for Test 1003871 (c) vertical component and (d) spectral ratios. Smoke was released from 06:56 to 07:27. The stable release point was used.

3.3 Upper-air Data

3.3.1 Description of the Upper-air Data

Ten instrumented balloon releases were made during the course of the AMADEUS Dispersion Experiments. The dates, times and maximum heights reached are summarized in Table 3.27 below. The soundings were made available to us in the form of photocopies of the printer outputs produced in the field; the format of these outputs varied from case to case. The data on these sheets were manually transferred to computer compatible form. Because over 28 full pages of numerical values were involved, the data were first entered by one person and then independently checked by two others. In this way, the integrity of the data was ensured.

Table 3.27 Balloon soundings for Meadowbrook study.

Date	Start	Stop	Max. Height (m)
9/23	13:21	13:36	1400
9/24	20:19	20:36	6000
9/26	07:48	08:06	6900
9/27	01:24	01:53	5600
9/28	07:17	07:44	8000
9/29	18:50	19:17	8000
9/30	15:34	16:02	7500
10/01	11:16	11:26	2100
10/02	09:06	09:27	2100
10/03	16:19	16:46	6300

Our primary interest in the instrumented-balloon data lies in determining the mixing heights for the unstable release periods. Two methods of making this determination are possible depending on the type of sounding which is available. If a sounding is made at or very near the time of the test, the mixing height can be determined directly by locating the first inversion in the potential temperature profile. If no contemporaneous upper-air data are available, then the ground-level temperature at the time of the test can be used in conjunction with a morning sounding to estimate the mixing height. This estimate is made by determining the height at which the upper-air potential temperature equals the surface-level potential temperature at the time of interest. The potential temperature is based on the entropy of air and is defined as the temperature which, at 1000 mb pressure, gives the same entropy as do the actual temperature and pressure.

3.3.2 Potential Temperature Profiles and Mixing Heights for Daytime Releases

The potential temperature profiles determined from the 10 upper-air soundings are presented in Figs. 3.20 – 3.29. No estimate of the mixing height is possible for Test 0921871, since the first sounding was not made until two days later. A contemporaneous sounding is available for Test 0923871; morning soundings must be used the other three convective cases (Tests 0926871, 0928871 and 1002872). The mixing heights thus determined are summarized in Table 3.28.

Table 3.28 Boundary layer heights for four tests.

Test	Times	z_i (m)
0923871	14:00 – 14:50	410
0926871	12:00 – 13:07	910
0928871	10:29 – 10:54	300
1002872	12:16 – 12:34	520

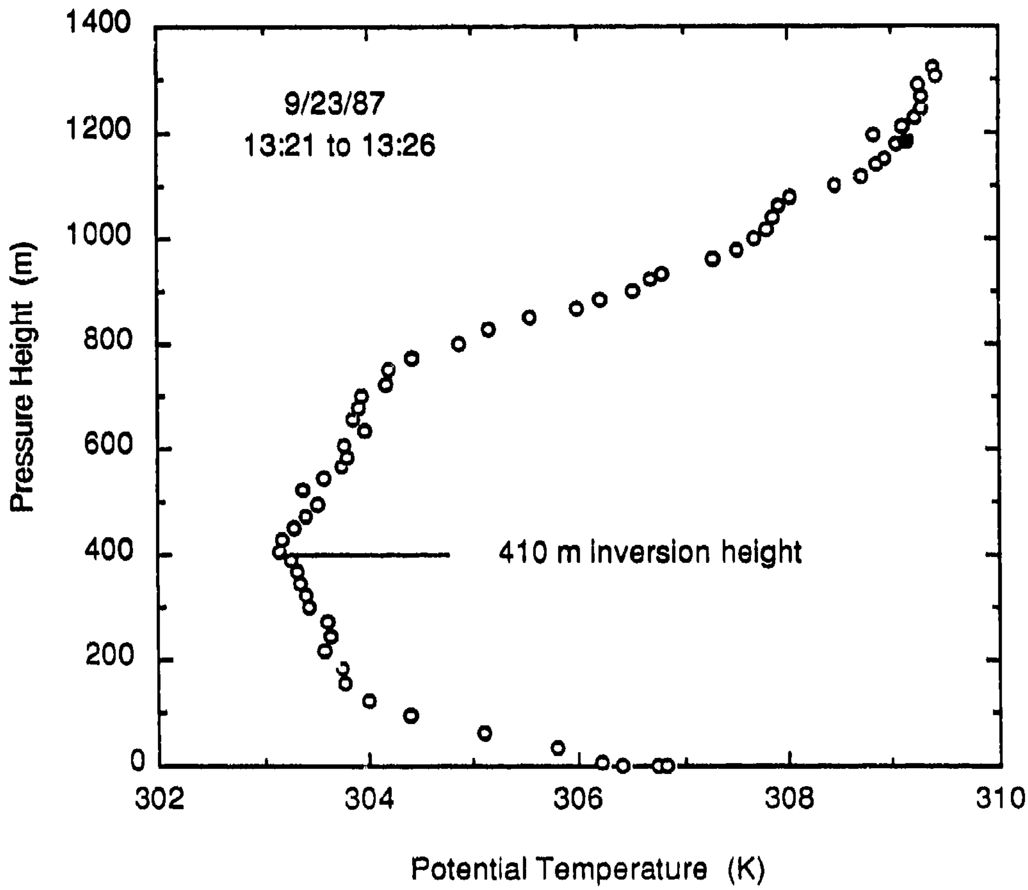


Figure 3.19 Potential temperature profile for Setember 23, 1987. This sounding was taken immediately prior to Test 0923871. An inversion at 410 m is clearly visible.

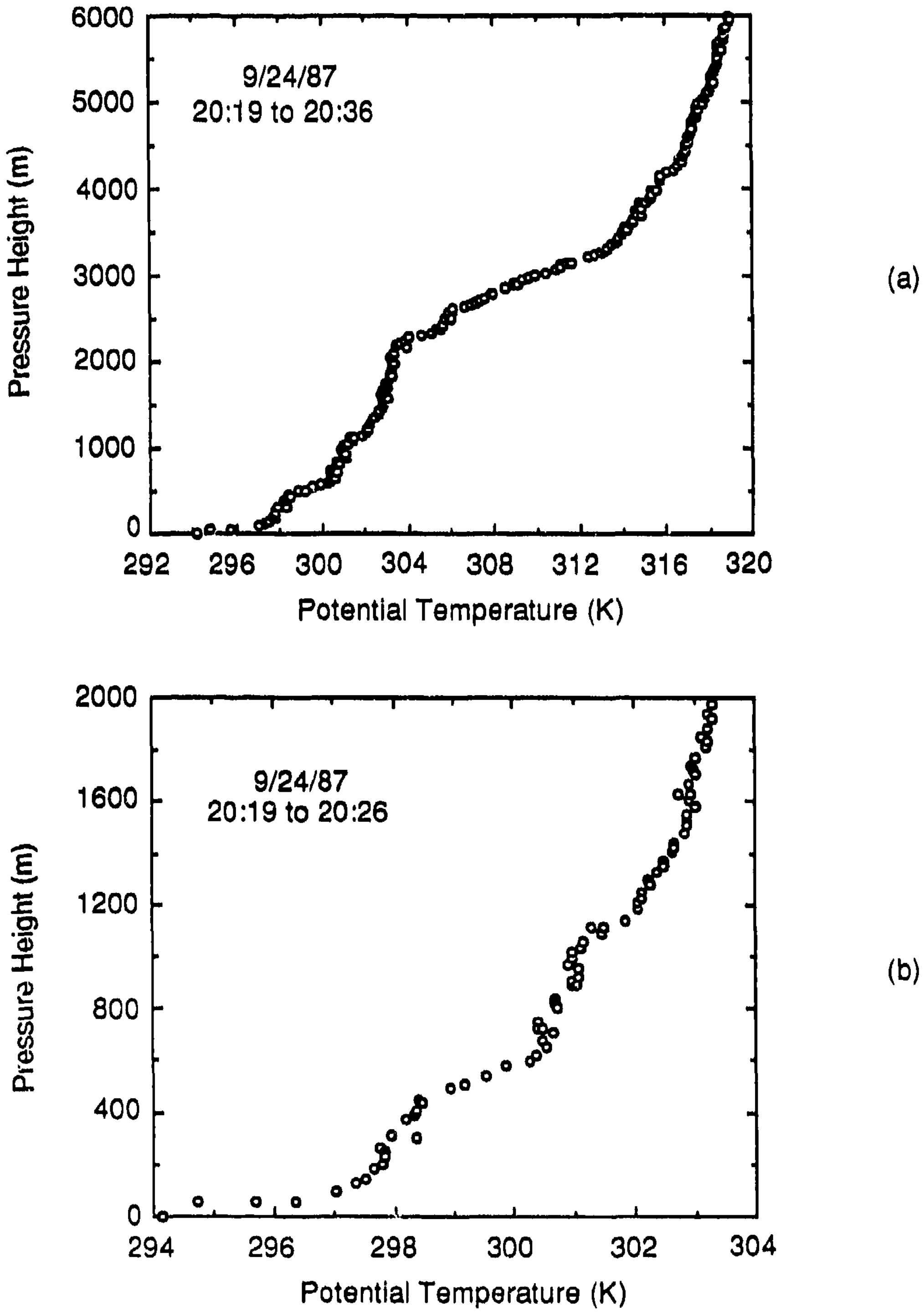
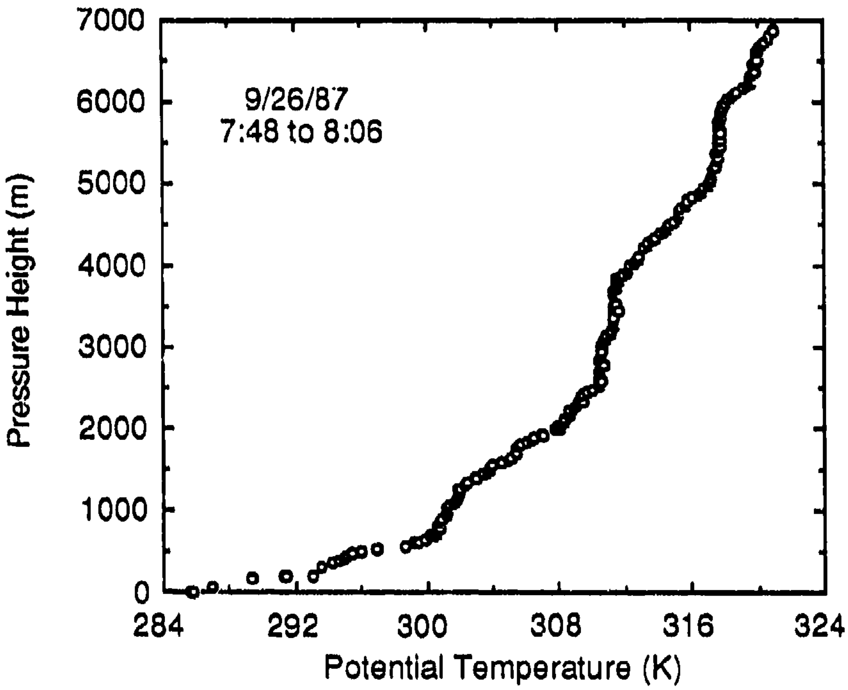
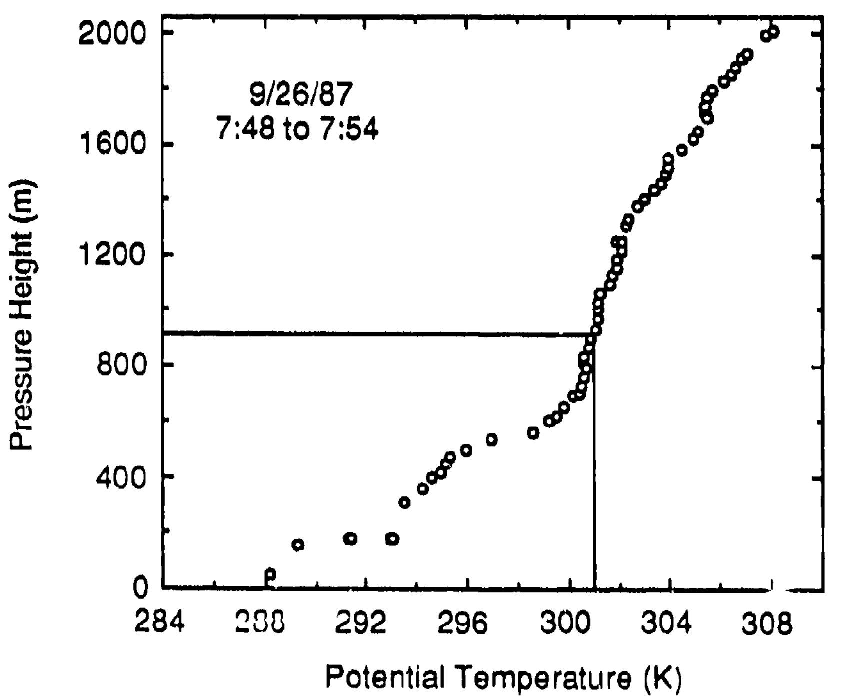


Figure 3.20 Potential temperature profile for September 24, 1987. (a) to a height of 6000 m and (b) to a height of 2000 m.



(a)



(b)

Figure 3.21 Potential temperature profile for September 26, 1987. (a) to a height of 6900 m and (b) to a height of 2000 m. The potential temperature at time of Test 0926871 was used with the morning profile to obtain a boundary layer height of 915 m for this test.

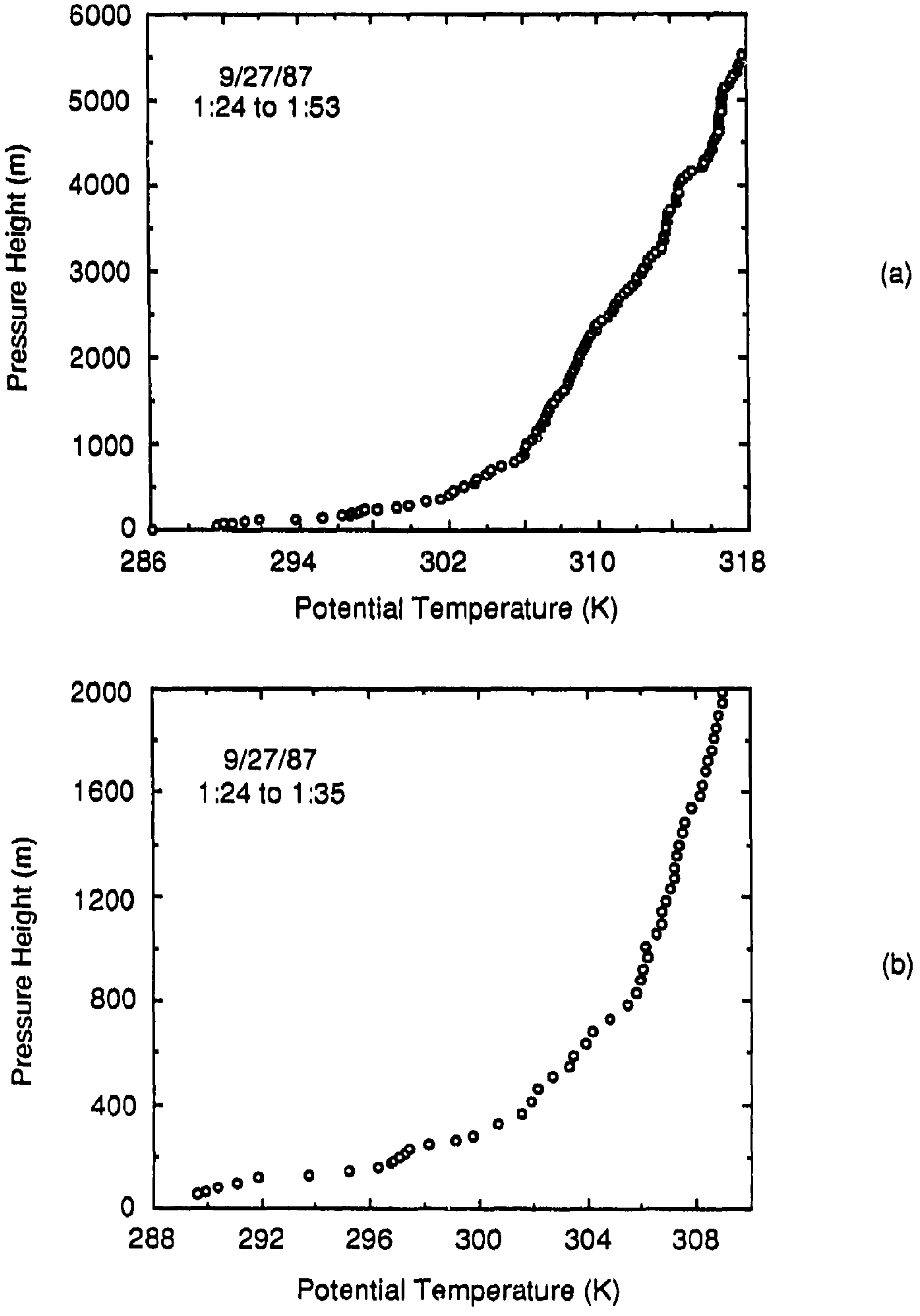


Figure 3.22 Potential temperature profile for September 27, 1987. (a) to a height of 5600 m and (b) to a height of 2000 m.

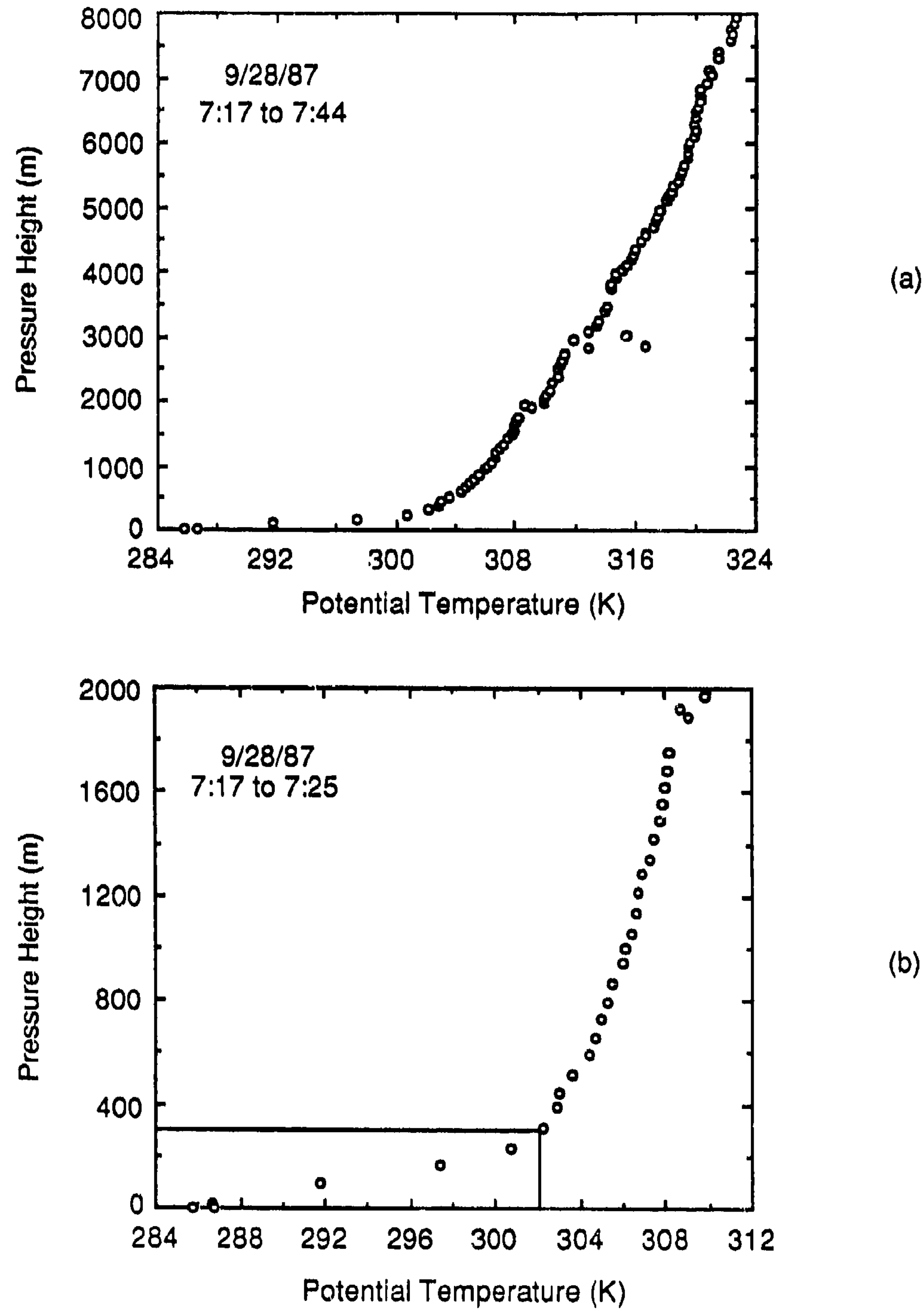
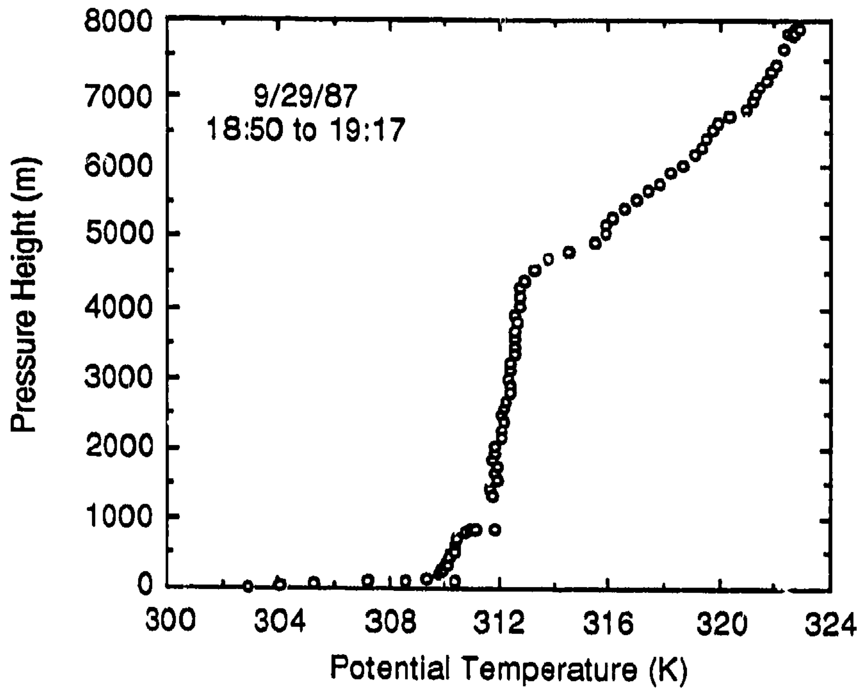
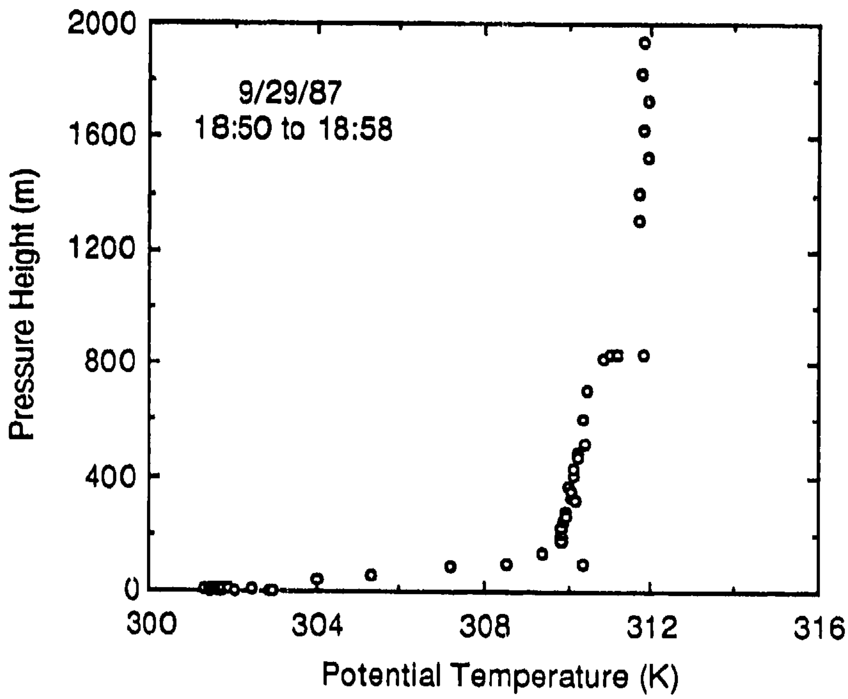


Figure 3.23 Potential temperature profile for September 28, 1987. (a) to a height of 8000 m and (b) to a height of 2000 m. The potential temperature at time of Test 0928871 was used with the morning profile to obtain a boundary layer height of 300 m for this test.

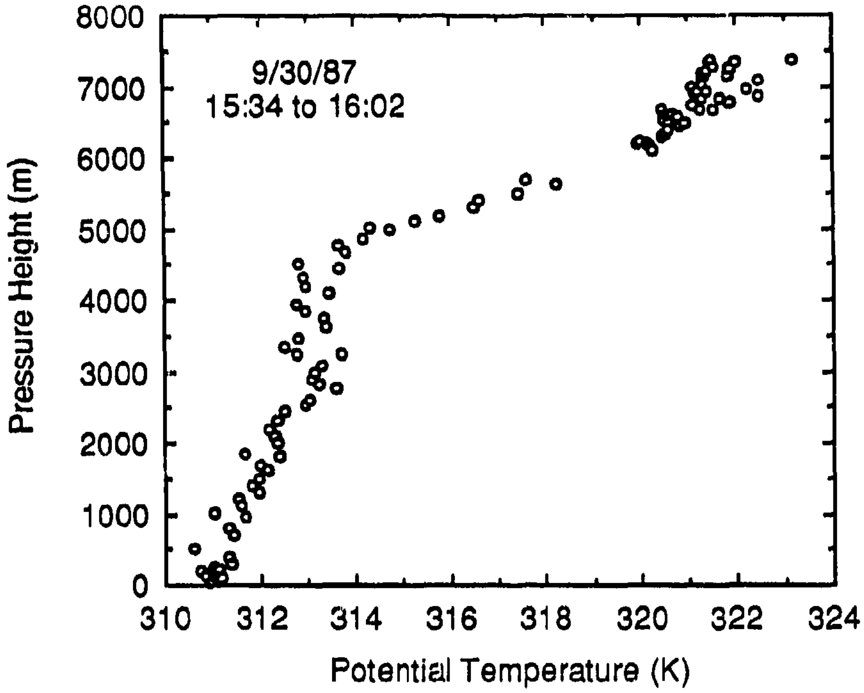


(a)

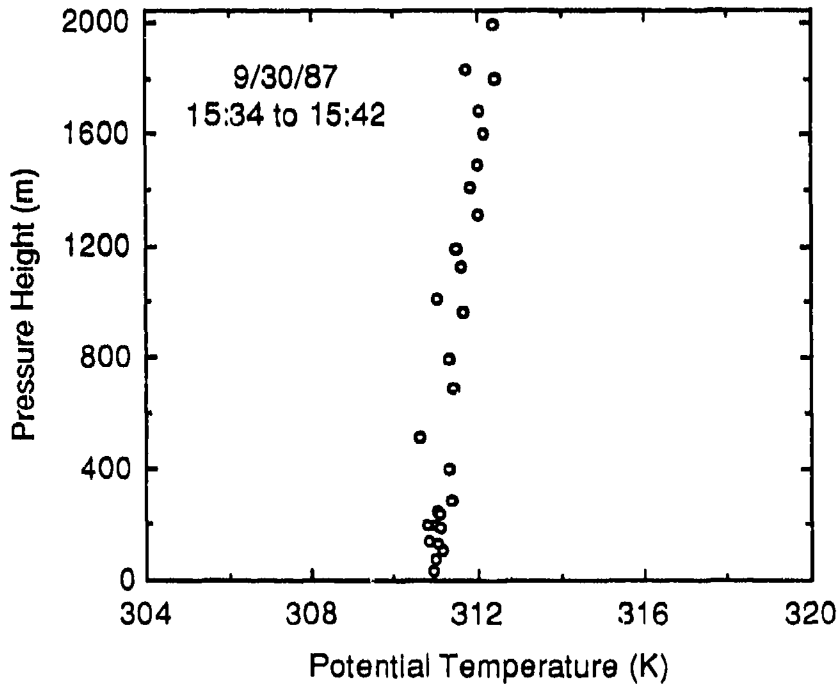


(b)

Figure 3.24 Potential temperature profile for September 29, 1987. (a) to a height of 8000 m and (b) to a height of 2000 m.



(a)



(b)

Figure 3.25 Potential temperature profile for September 30, 1987. (a) to a height of 7600 m and (b) to a height of 2000 m.

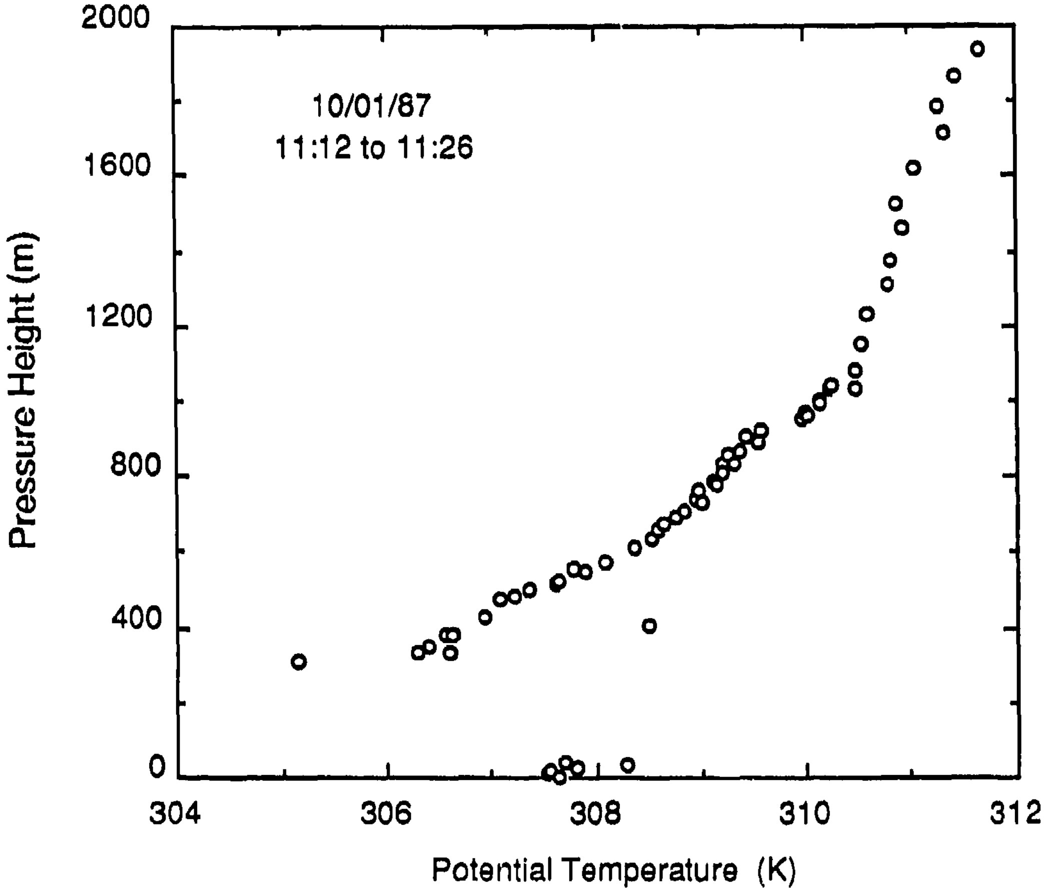


Figure 3.26 Potential temperature profile for October 1, 1987.

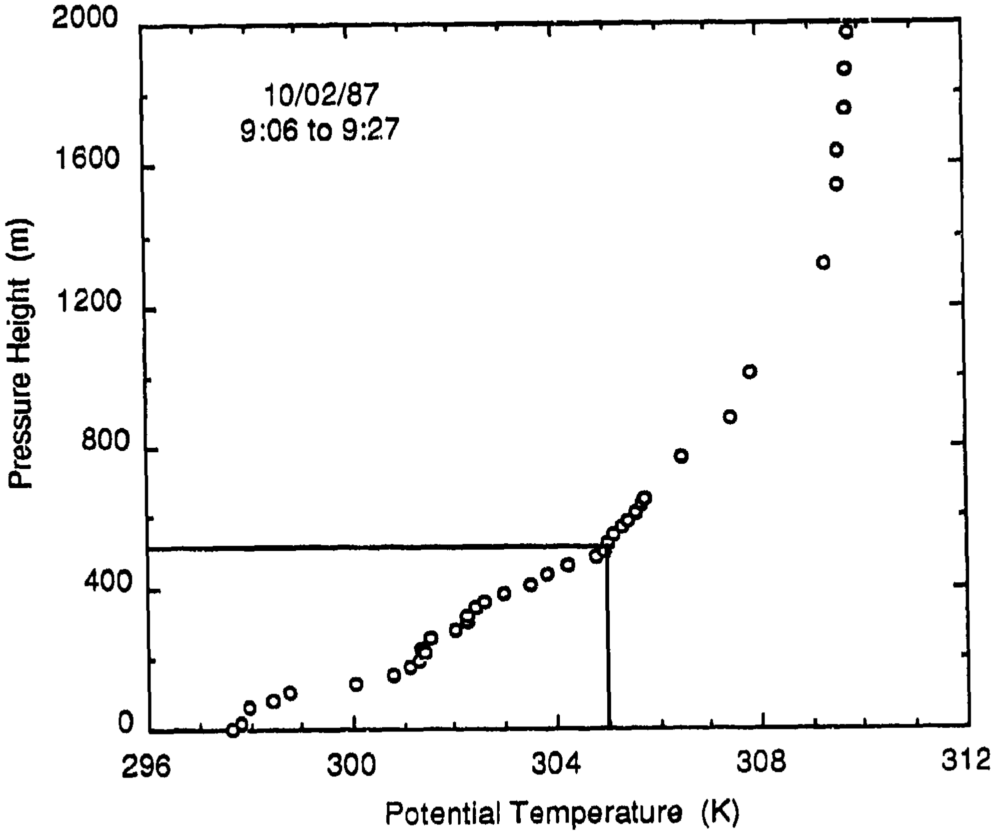
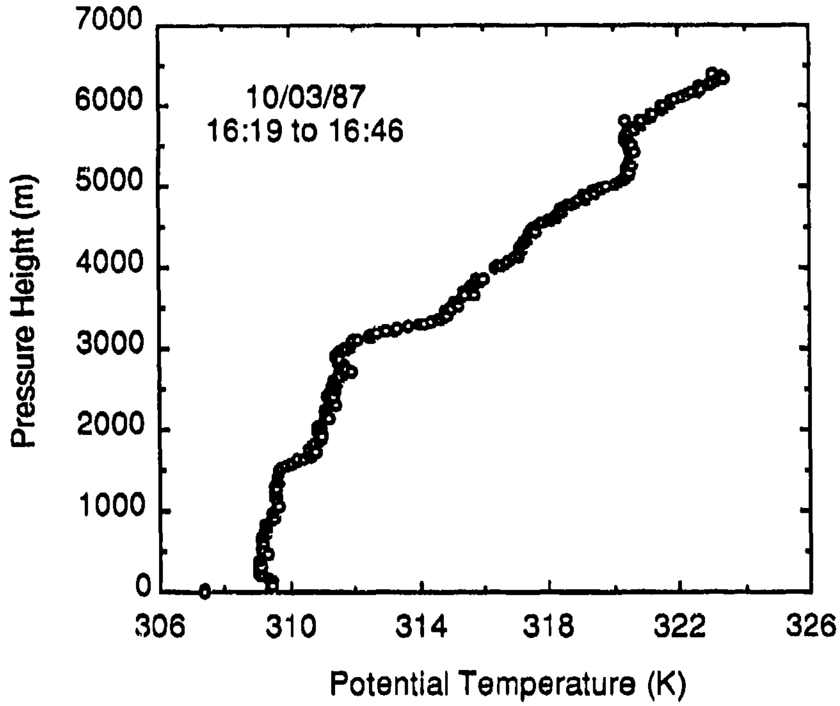
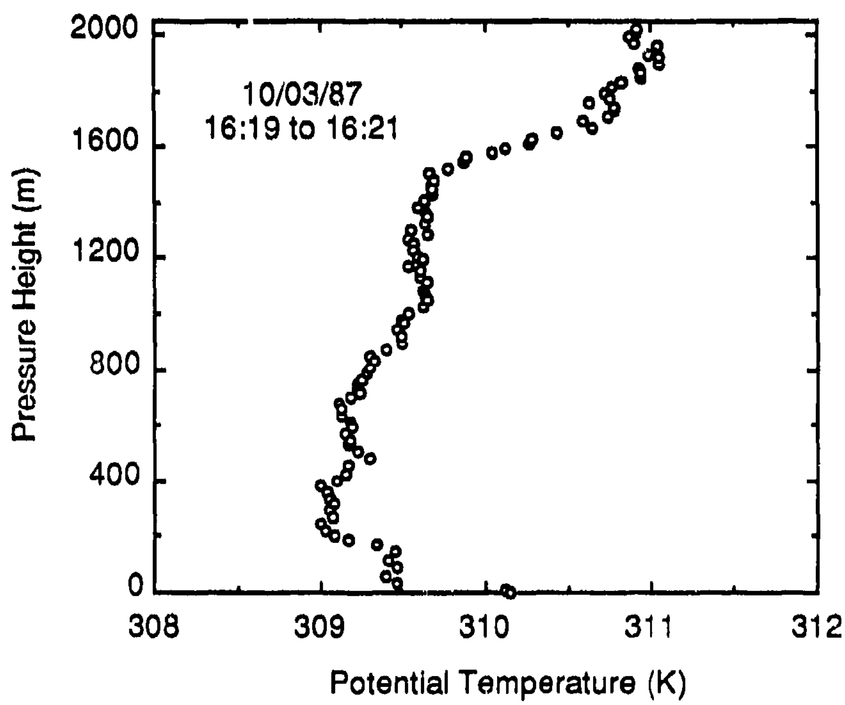


Figure 3.27 Potential temperature profile for October 2, 1987. The boundary layer height of 520 m for Test 1002872 was obtained by intersecting the potential temperature at the time of the test with the morning potential temperature profile.



(a)



(b)

Figure 3.28 Potential temperature profile for October 3, 1987. (a) to a height of 6500 m and (b) to a height of 2000 m

3.4 Sonic-anemometer Data

3.4.1 Description of Sonic-anemometer Data

Two sonic anemometers (designated A and B) were operated by researchers from Risø National Laboratory in Denmark. Sonic Anemometer A, which only operated during the daytime dispersion tests, was located at UTM coordinates 4462474 N and 585523 E which is close to our unstable release point. Sonic Anemometer B, which operated almost continuously between September 21, 1987 and October 4, 1987, was located at UTM coordinates 4462417 N and 586756 E which is near the 30-m micrometeorological instrument tower. Fig. 2.1 shows the location of the two anemometers within the test area.

A local data acquisition system sampled the anemometer outputs at the rate of 20 Hz. Ten-min averages of sonic anemometer data were made available to us on nine-track computer tape. These data include

(a) the vector-mean wind speed U (m/s),

(b) the vector-mean wind direction θ (°),

(c) the mean temperature T (°C),

(d) the turbulent kinetic energy E computed from the correlation $\frac{1}{2}(\overline{u'^2} + \overline{v'^2} + \overline{w'^2})$ (m^2/s^2),

(e) the heat flux correlation H given by $\rho C_p \overline{T'w'}$ (W/m^2),

(f) z / L, where z is the measurement height of 7 m and L is the Monin-Obukov length defined by

$$L = \frac{-u_*^3}{\kappa(g/T)Q_o}\text{, and} \tag{3.23}$$

(g) the friction velocity u_* given by $\sqrt{\overline{u'w'} + \overline{v'w'}}$ (m/s).

3.4.2 Synopsis of Sonic-anemometer Data

Since the sonic anemometer data exist only as 10-min averages, we do not have the flexibility to choose averaging times to the nearest minute. In selecting the appropriate averaging times, we attempted to include as much data as possible without exceeding the time period of the test by more than fifteen minutes. The sonic-anemometer data are presented in Tables 3.29 – 3.41. Here, the individual 10-min statistics are listed along with the parameter 1 / L which was obtained from z / L by dividing by z = 7 m. Because several of the 10-min averages appear inconsistent with the other results, we also calculated filtered averages with the suspect data removed.

Two other important parameters, easily computed from the sonic-anemometer data and a knowledge of the boundary layer height, are the convective velocity scale w_* and temperature scale T_* defined by

$$w_* = u_* \left(- \frac{z_i}{\kappa L} \right)^{1/3} , \qquad (3.24)$$

and

$$T_* = \frac{\overline{T'w'}}{w_*} . \qquad (3.25)$$

Estimates of these parameters along with the length scale ratio ($-z_i$ / L) are given in Table 3.41 for the four unstable tests for which boundary layer heights are available.

Table 3.29 Sonic-anemometer data for Test 0921871. Smoke was released from 14:30 to 15:00. The unstable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

(a) Sonic Anemometer A

Start Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
14:25*	4.35	287	41.8	1.54	150.09	-0.40	0.29	-0.057
14:35	4.42	276	42.2	2.45	174.67	-0.01	1.07	-0.001
14:45	4.20	278	41.9	2.02	115.54	-0.02	0.78	-0.003
14:55	5.33	275	42.2	2.20	205.73	-0.01	1.00	-0.001
15:05	5.26	269	42.1	1.99	75.95	-0.02	0.68	-0.003
Average	4.71	277	42.0	2.04	144.40	-0.09	0.76	-0.013
Filtered	4.80	274.50	42.10	2.17	142.97	-0.02	0.88	-0.002

(b) Sonic Anemometer B

Start Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
14:25	3.55	307	38.5	2.52	94.32	-0.01	0.99	-0.001
14:35*	3.26	295	38.7	1.59	123.05	-0.38	0.28	-0.054
14:45	3.67	316	39.0	2.14	128.87	-0.01	0.99	-0.001
14:55	3.17	302	39.0	2.26	159.15	-0.14	0.42	-0.020
15:05	4.75	288	38.9	3.20	146.21	-0.03	0.66	-0.004
Average	3.68	301	38.8	2.34	130.32	-0.11	0.67	-0.016
Filtered	3.79	303.15	38.85	2.53	132.14	-0.05	0.77	-0.007

Table 3.30 Sonic-anemometer data for Test 0923871. Smoke was released from 14:00 to 15:31. The smoke moved off the grid at 14:50. The unstable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

(a) Sonic Anemometer A

Start Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
13:55	2.57	275	33.4	1.63	263.95	-0.03	0.83	-0.004
14:05	3.06	275	33.7	1.57	260.07	-0.02	0.94	-0.003
14:15	2.98	298	33.8	0.77	192.79	-0.10	0.51	-0.014
14:25*	3.08	273	34.1	0.79	172.00	-2.66	0.16	-0.380
14:35	3.21	282	34.3	1.13	148.80	-0.06	0.57	-0.009
14:45	1.84	240	34.6	2.86	163.03	0.00	1.46	0.000
14:55	0.83	238	34.6	1.30	169.50	-0.02	0.87	-0.003
Average	2.51	268.71	34.07	1.44	195.73	-0.41	0.76	-0.059
Filtered	2.42	268.00	34.07	1.54	199.69	-0.04	0.86	-0.005

(b) Sonic Anemometer B

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
13:55	3.08	268	30.1	1.29	147.50	-0.03	0.72	-0.004
14:05	2.90	276	30.5	1.23	173.38	-0.03	0.70	-0.004
14:15	3.87	265	30.6	1.07	150.09	-0.14	0.42	-0.020
14:25*	2.69	303	30.8	1.28	161.73	-0.36	0.32	-0.051
14:35	3.58	277	31.0	0.91	200.55	-0.07	0.59	-0.010
14:45	2.22	249	31.3	1.93	261.36	-0.06	0.66	-0.009
14:55	2.33	251	31.3	1.06	127.83	-0.04	0.63	-0.006
Average	2.95	269.67	30.80	1.25	174.63	-0.10	0.58	-0.015
Filtered	3.00	264.20	30.80	1.25	176.79	-0.06	0.62	-0.009

Table 3.31 Sonic-anemometer data for Test 0925871. Only Sonic Anemometer B operated. Smoke was released from 00:18 to 01:03. The stable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
00:15	0.45	352	15.5	0.08	-16.95	0.12	0.22	0.017
00:25	0.65	47	15.5	0.08	-6.34	0.05	0.21	0.007
00:35	0.63	36	15.6	0.04	-8.35	0.14	0.16	0.020
00:45*	0.19	195	15.5	0.05	29.63	-0.37	0.18	-0.053
00:55	0.28	25	15.5	0.11	-37.65	0.09	0.31	0.013
01:05	0.52	71	15.7	0.19	-10.03	0.42	0.12	0.060
Average	0.45	121	15.6	0.09	-8.28	0.08	0.20	0.011
Filtered	0.51	106.16	15.56	0.10	-15.86	0.16	0.20	0.023

Table 3.32 Sonic-anemometer data for Test 0926871. Smoke was released from 12:00 to 13:07. The unstable release point was used. No filtering was deemed necessary for this test.

(a) Sonic Anemometer A

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
11:55	5.00	308	28.4	1.50	282.06	-0.16	0.50	-0.023
12:05	4.15	314	28.6	1.88	258.77	-0.02	0.99	-0.003
12:15	4.02	307	28.9	2.46	209.61	-0.01	1.27	-0.001
12:25	5.35	311	29.0	1.75	284.65	-0.19	0.47	-0.027
12:35	5.12	306	29.4	2.11	304.06	-0.03	0.87	-0.004
12:45	5.21	294	29.8	1.91	367.46	-0.11	0.61	-0.016
12:55	5.60	304	29.7	1.85	187.61	-0.02	0.92	-0.003
Average	4.92	306	29.1	1.92	270.60	-0.08	0.80	-0.011

(b) Sonic Anemometer B

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
11:55	3.26	308	24.8	3.87	200.55	-0.01	1.02	-0.001
12:05	3.77	300	24.9	1.55	156.56	-0.07	0.53	-0.010
12:15	2.14	321	25.6	2.52	163.03	-0.02	0.83	-0.003
12:25	3.62	322	25.5	1.54	155.26	-0.10	0.49	-0.014
12:35	4.17	278	25.9	3.20	195.37	-0.05	0.65	-0.007
12:45	4.88	264	26.2	2.28	188.91	-0.04	0.72	-0.006
12:55	3.39	315	26.3	2.11	157.85	-0.05	0.61	-0.007
13:05	4.04	284	26.9	3.68	247.13	-0.01	1.08	-0.001
Average	3.66	299	25.8	2.59	183.08	-0.04	0.74	-0.006

Table 3.33 Sonic-anemometer data for Test 0927871. Only Sonic Anemometer B operated for this test. Smoke was released from 03:19 to 03:39. The stable release point was used.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
03:15*	0.33	113	11.1	0.08	-8.59	0.35	0.12	0.050
03:25	0.32	36	10.5	0.08	1.91	-0.17	0.09	-0.024
03:35	0.23	65	10.5	0.09	13.33	-0.21	0.17	-0.030
03:45	0.76	26	10.3	0.06	8.77	-0.15	0.16	-0.021
Average	0.41	60	10.6	0.08	3.86	-0.05	0.14	-0.006
Filtered	0.44	42.33	10.43	0.08	8.00	-0.18	0.14	-0.025

Table 3.34 Sonic-anemometer data for Test 0927872. Only Sonic Anemometer B operated for this test. Smoke was released from 06:44 to 06:54. The stable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
06:45*	1.24	27	8.8	0.18	17.08	-0.41	0.15	-0.059
06:55	0.91	69	9.3	0.23	-46.71	0.14	0.30	0.020
07:05	0.61	47	8.5	0.12	-10.84	0.05	0.26	0.007
Average	0.92	48	8.9	0.18	-13.49	-0.07	0.24	-0.010
Filtered	0.76	58.00	8.94	0.18	-28.78	0.10	0.28	0.014

Table 3.35 Sonic-anemometer data for Test 0928871. Smoke was released from 10:29 to 10:54. The unstable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

(a) Sonic Anemometer A

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
10:25	2.38	261	28.4	0.19	105.97	-1.38	0.18	-0.197
10:35	2.64	268	28.6	0.30	101.44	-0.80	0.21	-0.114
10:45*	2.96	265	28.8	0.20	93.68	-10.28	0.09	-1.469
10:55	2.60	257	29.4	0.32	138.44	-0.32	0.31	-0.046
Average	2.65	263	28.8	0.25	109.88	-3.20	0.20	-0.456
Filtered	2.54	262.00	28.80	0.27	115.28	-0.83	0.23	-0.119

(b) Sonic Anemometer B

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
10:25	2.69	266	25.7	0.24	72.07	-1.28	0.16	-0.183
10:35	3.10	269	25.9	0.26	67.80	-1.18	0.16	-0.169
10:45	3.54	272	25.9	0.34	57.45	-0.57	0.19	-0.081
10:55*	3.45	262	26.2	0.22	69.87	-6.83	0.09	-0.976
Average	3.20	267.05	25.93	0.27	66.80	-2.47	0.15	-0.352
Filtered	3.11	268.70	25.83	0.28	65.77	-1.01	0.17	-0.144

Table 3.36 Sonic-anemometer data for Test 0930871. Only Sonic Anemometer B operated for this test. Smoke was released from 06:48 to 07:28. The stable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
06:45	1.33	57	17.1	0.18	-57.32	0.38	0.22	0.054
06:55	1.42	72	17.1	0.14	-7.34	0.30	0.12	0.043
07:05	1.14	55	17.2	0.07	-6.31	0.06	0.19	0.009
07:15*	1.14	36	17.3	0.11	2.68	-0.07	0.14	-0.010
07:25	1.01	72	17.0	0.16	-20.05	0.39	0.16	0.056
07:35	0.33	109	16.6	0.23	-21.35	0.06	0.30	0.009
Average	1.06	67	17.1	0.15	-18.28	0.19	0.19	0.027
Filtered	1.05	73.00	17.00	0.16	-22.47	0.24	0.20	0.034

Table 3.37 Sonic-anemometer data for Test 1001871. Only Sonic Anemometer B operated for this test. Smoke was released from 06:52 to 07:32. The stable release point was used. No filtering was deemed necessary for this test.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
06:45	1.07	40	18.8	0.20	-13.84	0.04	0.29	0.006
06:55	0.77	92	18.2	0.24	-41.15	0.45	0.19	0.064
07:05	0.41	76	18.6	0.09	-38.69	0.34	0.20	0.049
07:15	1.46	45	18.5	0.32	-54.21	0.07	0.39	0.010
07:25	0.85	73	18.6	0.24	-55.90	0.23	0.26	0.033
07:35	1.14	65	18.4	0.21	-4.52	0.03	0.23	0.004
Average	0.95	65	18.5	0.22	-34.72	0.19	0.26	0.028

Table 3.38 Sonic-anemometer data for Test 1002871. Only Sonic Anemometer B operated for this test. Smoke was released from 07:17 to 07:47. The stable release point was used. No filtering was deemed necessary for this test.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
07:15	0.66	14	17.4	0.04	-2.65	0.73	0.06	0.104
07:25	0.81	56	17.7	0.05	-12.40	0.58	0.12	0.083
07:35	1.50	70	17.7	0.06	-6.30	0.56	0.09	0.080
07:45	1.45	65	17.3	0.06	-9.17	0.25	0.14	0.036
07:55	0.85	76	17.2	0.13	-31.83	0.62	0.16	0.089
Average	1.05	56	17.5	0.07	-12.47	0.55	0.11	0.078

Table 3.39 Sonic-anemometer data for Test 1002872. Smoke was released from 12:16 to 12:34. The unstable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

(a) Sonic Anemometer A

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
12:15	1.80	270	33.2	0.77	135.86	-0.16	0.39	-0.023
12:25*	2.09	275	33.8	0.64	179.85	-1.49	0.20	-0.213
12:35	2.23	281	34.1	1.08	205.73	-0.04	0.70	-0.006
Average	2.04	275	33.7	0.83	173.81	-0.56	0.43	-0.080
Filtered	2.02	275.50	33.65	0.93	170.80	-0.10	0.55	-0.014

(b) Sonic Anemometer B

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
12:15	3.19	244	30.3	0.38	103.90	-0.20	0.33	-0.029
12:25*	3.15	251	30.7	0.64	175.97	-7.12	0.12	-1.017
12:35	3.45	260	31.0	0.66	161.73	-0.13	0.44	-0.019
Average	3.26	252	30.7	0.56	147.20	-2.48	0.30	-0.355
Filtered	3.32	251.75	30.65	0.52	132.82	-0.17	0.39	-0.024

Table 3.40 Sonic-anemometer data for Test 1003871. Only Sonic Anemometer B operated for this test. Smoke was released from 06:56 to 07:27. The stable release point was used. Data for times marked with an asterisk (*) are not included in the filtered averages.

Time	U [m/s]	θ [°]	T [C]	E [m^2/s^2]	H [W/m^2]	z / L	u_* [m/s]	1/L [m^{-1}]
06:55	0.27	199	16.6	0.15	-2.46	0.01	0.30	0.001
07:05	0.67	59	16.6	0.26	18.11	-0.03	0.37	-0.004
07:15	0.55	58	17.1	0.14	-6.24	0.03	0.25	0.004
07:25*	0.49	264	17.4	0.12	18.89	-0.35	0.16	-0.050
Average	0.50	145	16.9	0.17	7.08	-0.09	0.27	-0.012
Filtered	0.50	105.43	16.77	0.18	3.14	0.00	0.31	0.000

Table 3.41 Convective scales for four of five unstable tests. These results are based on the "filtered" averages.

		Sonic Anemometer A			Sonic Anemometer B		
Test	z_i [m]	$-z_i / L$	w_*	T_*	$-z_i / L$	w_*	T_*
0923871	410	2.24	1.528	0.109	3.61	1.16	0.131
0926871	910	10.1	2.348	0.096	5.68	1.54	0.099
0928871	300	35.7	1.028	0.093	43.2	0.81	0.068
1002871	520	7.42	1.456	0.097	12.4	1.22	0.090

4. SUMMARY AND CONCLUSIONS

This report summarizes our effort to organize the large amount of meteorological data generated in the AMADEUS dispersion experiments into a form which is suitable for validating and improving smoke dispersion models. In addition, a preliminary analysis of the data was carried out. Averages of the surface-station and micrometeorological measurements were computed for each of the 12 smoke release periods. Also, the stability of the atmosphere was characterized by analyzing (i) the standard deviation of the horizontal wind direction, (ii) the bulk Richardson number, (iii) the vertical profiles of wind and temperature, and (iv) direct measurements of the vertical heat and momentum fluxes. For four of the five daytime releases, the height of the boundary layer was determined from the instrumented-balloon soundings.

A summary of the key variables for each of the 12 smoke dispersion trials is presented in Table 4.1. These results are divided into four broad categories. First, basic information about the release is given. This information includes (a) the start and stop times of the test, (b) the total time of smoke release (which may be less than the total elapsed time due to generator failure), (c) the total mass of fog oil consumed, (d) the average release rate based on the mass of oil used and the duration of the release, (e) the release point (stable or unstable) used, and (f) the cloud cover at the time of the test. Next, the data from the 14 10-m surface stations is summarized. To gain insight into the spatial inhomogeneity of the wind and temperature fields at the site, the maximum and minimum (mean) values are given, along with appropriate ratios or differences. Third, data from the 30-m micrometeorological instrument tower are presented. The 8-m and 30-m levels were chosen to illustrate the variation with the height. And lastly, six basic scaling parameters are presented: (i) the Monin-Obukov length L, (ii) the mixing height z_i, (iii) the convective scale ratio ($-z_i / L$), (iv) the friction velocity u_*, (v) the convective velocity scale w_* and (vi) the convective temperature scale T_*. The mixing height and thus the convective scales are available for only four of the five daytime releases.

The results show that the meteorological data are complete and consistent, both internally and with other studies of the atmospheric boundary layer. The daytime convective conditions reveal a high degree of coherency, whereas the nighttime stable conditions are more spatially heterogeneous and less coherent. The stable boundary layer is generally less well understood than is the convective boundary layer, especially in a complex terrain setting. The data appear to offer significant potential for improving the state of dispersion modeling in this important area.

Table 4.1 Source and meteorological data for the AMADEUS smoke dispersion experiments.

Test	0921871	0923871	0925871	0926871	0927871	0927872	0928871	0930871	1001871	1002871	1002872	1003871
Start Time	14:30	14:00	00:18	12:00	03:19	06:44	10:29	06:48	06:52	07:17	12:16	06:56
Stop Time	15:00	14:50 (off grid)	01:03	13:07	03:39	06:54	10:54	07:28	07:32	07:47	12:34	07:27
Release Time [min]	30	40	45	67	20	10	25	40	40	30	17	31
Total Mass Released [kg]	N/A	63.0	109.0	181.2	53.4	20.8	49.1	97.0	71.8	73.4	35.0	52.4
Release Rate [g/s]	N/A	26.3	40.4	45.1	44.5	34.7	32.7	40.4	29.9	40.8	34.3	28.2
Release Point	Unstable	Unstable	Stable	Unstable	Stable	Stable	Unstable	Stable	Stable	Stable	Unstable	Stable
Cloud Cover	Clear	Thin Overcast	Partly Cloudy	Clear	Clear	Clear	Clear	Clear	Clear	Partly Cloudy	Partly Cloudy	Cirrus Clouds
Data from 10-m Surface Stations (U = wind speed; θ = wind direction; T = temperature; Ri_b = bulk Richardson number; max, min and variation taken over all 14 stations)												
U_{max} [m/s]	5.536	3.048	3.011	6.34	3.741	3.568	3.65	4.295	3.716	3.482	3.421	3.579
U_{min} [m/s]	2.883	1.417	0.323	1.92	0.218	0.425	1.637	0.853	0.77	0.685	0.190	0.432
U_{min} / U_{max}	0.521	0.46	0.107	0.303	0.058	0.12	2.013	0.20	0.207	0.197	0.056	0.121
$T_{10,max}$ [C]	38.54	30.58	19.53	26.78	21.65	20.28	27.29	25.20	27.33	24.80	31.97	25.49
$T_{10,min}$ [C]	36.87	29.03	15.27	24.20	11.50	9.76	25.70	17.21	18.02	17.37	29.03	17.68
Variation in T [C]	1.67	1.55	4.26	2.58	10.15	10.52	1.59	7.99	9.31	7.43	2.96	7.81
θ_{max} [°]	332.9	334.1	190.2	316.6	156.8	158.0	327.2	159.7	161.2	159.6	320.0	163.3
θ_{min} [°]	274.2	227.5	52.73	238.4	20.1	57.5	226.7	42.2	52.5	51.0	74.11	63.14
Variation in θ [°]	58.7	106.6	137.47	78.2	136.7	101.5	100.5	117.5	108.7	108.6	245.39	100.16
$Ri_{b,max}$	-0.028	-0.086	3.31	-0.067	4.70	1.418	-0.072	1.072	0.696	1.067	-0.109	1.851
$Ri_{b,min}$	-0.006	-0.016	0.021	-0.007	0.052	0.041	-0.024	0.026	0.014	0.021	-0.014	0.036
$Ri_{b,min}$ / $Ri_{b,max}$	0.214	0.186	0.006	0.104	0.011	0.029	0.333	0.024	0.020	0.020	0.128	0.019
Data from 30-m Micrometeorological Tower (U = wind speed; θ = wind direction; T = temperature; u, v, w = wind velocity components; σ = standard deviation; subscripts denote height in m)												
U_8 [m/s]	3.184	2.382	0.302	3.156	0.432	0.589	2.728	0.953	0.669	0.813	2.700	0.284
U_{30} [m/s]	3.331	2.512	1.203	3.286	1.050	1.358	2.131	1.739	1.915	1.709	2.934	1.482
θ_8 [°]	297.6	269.6	67.0	292.0	82.2	73.6	259.9	70.1	76.3	68.4	244.5	135.1
θ_{30} [°]	301.5	267.5	86.7	295.6	83.1	79.6	262.2	81.0	87.7	82.4	246.8	94.7
T_8 [C]	38.66	30.40	15.55	26.19	11.44	9.66	26.77	17.78	19.05	18.00	30.40	17.27
T_{30} [C]	38.29	30.05	16.24	25.79	13.09	11.62	26.53	18.96	20.25	18.75	30.05	18.56
σ_{u8} [m/s]	1.194	1.138	0.283	1.436	0.266	0.491	0.515	0.330	0.424	0.490	0.686	0.389
σ_{u30} [m/s]	1.198	1.082	0.361	1.372	0.327	0.377	0.552	0.532	0.643	0.583	0.530	0.696
σ_{v8} [m/s]	1.586	1.082	0.308	1.600	0.415	0.417	0.388	0.418	0.501	0.286	0.633	0.484
σ_{v30} [m/s]	1.700	1.052	0.174	1.624	0.370	0.218	0.383	0.342	0.353	0.290	0.602	0.316
σ_{w8} [m/s]	0.4014	0.3162	0.0586	0.4350	0.0817	0.1152	0.2148	0.0958	0.1253	0.0963	0.2594	0.1140
σ_{w30} [m/s]	0.7115	0.5852	0.1537	0.7838	0.1573	0.1819	0.2977	0.2004	0.2252	0.1821	0.4368	0.2094
$\sigma_{\theta 8}$ [°]	27.3	29.1	64.2	31.2	48.4	47.0	8.6	26.9	42.6	30.6	13.9	69.6
$\sigma_{\theta 30}$ [°]	28.2	28.2	11.6	32.4	22.0	10.2	11.0	13.9	12.0	11.9	12.3	19.7
Scaling Parameters (L = Monin-Obukov length; z_i = inversion height; u_* = friction velocity; w_* = convective velocity scale; T_* = convective temperature scale)												
L [m]	-470	-250	43	-91	-40	74	-8.4	29	36	13	-91	1000
z_i [m]	N/A	410	N/A	910	N/A	N/A	300	N/A	N/A	N/A	520	N/A
$-z_i$ / L	N/A	22	N/A	10	N/A	N/A	35.7	N/A	N/A	N/A	7.4	N/A
u_* [m/s]	0.88	0.86	0.20	0.80	0.14	0.28	0.23	0.20	0.26	0.11	0.52	0.31
w_* [m/s]	N/A	1.53	N/A	2.35	N/A	N/A	1.028	N/A	N/A	N/A	1.46	N/A
T_* [C]	N/A	0.109	N/A	0.096	N/A	N/A	0.093	N/A	N/A	N/A	0.097	N/A

APPENDIX A: FORMAT AND SAMPLE OF RAW DATA

A.1 STATIONS A101, A102 AND A105 - A110

HOURLY RECORDS

Channel	Units	Measurement
01		Program ID
02	XXXX	Station ID
03		UNKNOWN
04		UNKNOWN
05		UNKNOWN
06		UNKNOWN

ONE-MINUTE RECORDS

Channel	Units	Measurement
01		Program ID
02	YY	Year
03	JJJ	Julian Day
04	HHMM	Time
05	C	10-m Temperature (Computed by adding ΔT and T at 2 m)
06	C	2-m Temperature
07		UNKNOWN
08	m/s	10-m Wind Speed (Arithmetic Mean)
09	m/s	10-m Wind Speed (Vector Sum)
10	°	10-m Wind Direction (Vector Sum)
11	°	10-m Wind Direction (Standard Deviation)
12	C	Soil Temperature

SAMPLE RAW DATA RECORD FOR STATION A101

Notice the Hourly Record Appearing on Line 3

```
01+0113.  02+0087.  03+0266.  04+0000.  05+20.89  06+18.34  07-6999.  08+0.947
09+0.940  10+161.5  11+6.726  12+17.49
01+0204.  02+1083.  03+17.74  04+10.00  05+11.71  06+11.72
01+0113.  02+0087.  03+0266.  04+0001.  05+20.73  06+19.03  07-6999.  08+0.997
09+0.992  10+145.6  11+5.466  12+17.47
01+0113.  02+0087.  03+0266.  04+0002.  05+20.80  06+19.74  07-6999.  08+1.170
09+1.149  10+143.5  11+10.84  12+17.45
01+0113.  02+0087.  03+0266.  04+0003.  05+20.83  06+19.82  07-6999.  08+1.033
09+0.994  10+117.8  11+15.86  12+17.42
01+0113.  02+0087.  03+0266.  04+0004.  05+20.90  06+19.69  07-6999.  08+0.926
09+0.905  10+100.5  11+12.02  12+17.41
01+0113.  02+0087.  03+0266.  04+0005.  05+20.90  06+19.70  07-6999.  08+1.224
09+1.205  10+122.4  11+10.12  12+17.39
01+0113.  02+0087.  03+0266.  04+0006.  05+20.85  06+19.66  07-6999.  08+1.146
09+1.116  10+111.8  11+13.02  12+17.37
01+0113.  02+0087.  03+0266.  04+0007.  05+20.81  06+18.76  07-6999.  08+1.219
09+1.199  10+112.8  11+10.25  12+17.36
```

01+0113.	02+0087.	03+0266.	04+0008.	05+20.92	06+19.30	07-6999.	08+1.252
09+1.213	10+104.6	11+14.26	12+17.34				
01+0113.	02+0087.	03+0266.	04+0009.	05+21.06	06+19.66	07-6999.	08+1.350
09+1.298	10+095.3	11+15.85	12+17.30				
01+0113.	02+0087.	03+0266.	04+0010.	05+21.00	06+19.74	07-6999.	08+1.314
09+1.285	10+097.3	11+12.13	12+17.31				
01+0113.	02+0087.	03+0266.	04+0011.	05+21.01	06+19.50	07-6999.	08+1.480
09+1.451	10+102.4	11+11.43	12+17.29				
01+0113.	02+0087.	03+0266.	04+0012.	05+20.93	06+19.56	07-6999.	08+1.385
09+1.357	10+110.0	11+11.52	12+17.28				
01+0113.	02+0087.	03+0266.	04+0013.	05+20.95	06+19.95	07-6999.	08+1.398
09+1.356	10+124.4	11+14.19	12+17.27				
01+0113.	02+0087.	03+0266.	04+0014.	05+20.94	06+19.56	07-6999.	08+1.379
09+1.314	10+127.8	11+17.60	12+17.25				
01+0113.	02+0087.	03+0266.	04+0015.	05+20.92	06+19.61	07-6999.	08+1.223
09+1.186	10+113.1	11+13.96	12+17.24				
01+0113.	02+0087.	03+0266.	04+0016.	05+20.94	06+19.19	07-6999.	08+0.894
09+0.871	10+116.6	11+12.96	12+17.23				
01+0113.	02+0087.	03+0266.	04+0017.	05+20.90	06+19.17	07-6999.	08+0.901
09+0.878	10+128.4	11+13.09	12+17.21				
01+0113.	02+0087.	03+0266.	04+0018.	05+20.92	06+19.43	07-6999.	08+1.354
09+1.338	10+135.9	11+08.88	12+17.19				
01+0113.	02+0087.	03+0266.	04+0019.	05+21.06	06+19.52	07-6999.	08+1.268
09+1.257	10+143.8	11+07.30	12+17.18				
01+0113.	02+0087.	03+0266.	04+0020.	05+21.21	06+19.56	07-6999.	08+1.190
09+1.179	10+142.0	11+07.61	12+17.16				

A.2 STATIONS A103 AND A104

HOURLY RECORDS (appears after 1-min record for 00 minute)

Channel	Units	Measurement
01		Program ID
02	XXXX	Station ID
03	m/s	Minimum Wind Speed During Hour
04	m/s	Maximum Wind Speed During Hour

ONE-MINUTE RECORDS

Channel	Units	Measurement
01		Program ID
02	JJJ	Julian Day
03	HHMM	Time
04	XXXX	Station ID
05	C	10-m Temperature
06	m/s	10-m Wind Speed (Arithmetic Mean)
07	m/s	10-m Wind Speed (Vector Sum)
08	°	10-m Wind Direction (Vector Sum)
09	°	10-m Wind Direction (Standard Deviation)

SAMPLE RAW DATA RECORD FOR STATION A104

Notice the Hourly Record Appearing on Line 3

```
01+0001.  02+0265.  03+2400.  04+0104.  05+20.25  06+3.061  07+3.035  08+62.21
09+07.49
01+0002.  02+0104.  03+1.375  04+5.893
01+0001.  02+0266.  03+0001.  04+0104.  05+20.28  06+3.388  07+3.370  08+59.25
09+5.979
01+0001.  02+0266.  03+0002.  04+0104.  05+20.36  06+3.183  07+3.091  08+58.17
09+13.79
01+0001.  02+0266.  03+0003.  04+0104.  05+20.30  06+2.758  07+2.528  08+57.73
09+23.38
01+0001.  02+0266.  03+0004.  04+0104.  05+20.05  06+2.185  07+2.155  08+56.06
09+09.53
01+0001.  02+0266.  03+0005.  04+0104.  05+20.02  06+2.954  07+2.838  08+54.96
09+16.04
01+0001.  02+0266.  03+0006.  04+0104.  05+20.05  06+2.660  07+2.562  08+56.80
09+15.49
01+0001.  02+0266.  03+0007.  04+0104.  05+20.10  06+2.455  07+2.403  08+65.81
09+11.83
01+0001.  02+0266.  03+0008.  04+0104.  05+20.06  06+2.643  07+2.614  08+58.55
09+08.54
01+0001.  02+0266.  03+0009.  04+0104.  05+20.14  06+3.249  07+3.227  08+68.40
09+6.585
01+0001.  02+0266.  03+0010.  04+0104.  05+20.13  06+3.470  07+3.309  08+63.54
09+16.30
01+0001.  02+0266.  03+0011.  04+0104.  05+20.18  06+3.462  07+3.438  08+59.18
09+6.665
01+0001.  02+0266.  03+0012.  04+0104.  05+20.24  06+3.470  07+3.348  08+61.11
09+15.19
01+0001.  02+0266.  03+0013.  04+0104.  05+20.29  06+3.871  07+3.640  08+54.81
09+19.78
01+0001.  02+0266.  03+0014.  04+0104.  05+20.12  06+2.742  07+2.638  08+57.67
09+15.75
01+0001.  02+0266.  03+0015.  04+0104.  05+20.15  06+3.126  07+3.063  08+56.75
09+11.53
01+0001.  02+0266.  03+0016.  04+0104.  05+20.35  06+3.241  07+3.188  08+64.61
09+10.36
01+0001.  02+0266.  03+0017.  04+0104.  05+20.18  06+3.380  07+3.149  08+57.92
09+21.17
01+0001.  02+0266.  03+0018.  04+0104.  05+20.21  06+3.282  07+3.142  08+54.17
09+16.71
01+0001.  02+0266.  03+0019.  04+0104.  05+20.07  06+2.881  07+2.745  08+53.72
09+17.54
01+0001.  02+0266.  03+0020.  04+0104.  05+19.98  06+2.979  07+2.813  08+55.73
09+19.10
```

A.3 STATIONS A111 - A114

ONE-SECOND DATA RECORDS

Field	Row	Column	Units	Measurement
1	1	1	YYMMDD	Date
2	1	2	HHMMSS	Time
			Wind Speed and Direction Data	
3	1	3	m/s	Wind speed at 10-m level of Station A114
4	1	4	m/s	Wind speed at 30-m level of Station A115
5	1	5	m/s	Wind speed at 10-m level of Station A111
6	1	6	m/s	Wind speed at 10-m level of Station A112
7	1	7	m/s	Wind speed at 10-m level of Station A113
8	2	1	°	Wind direction at 10-m level of Station A114
9	2	2	°	Wind direction at 30-m level of Station A115
10	2	3	°	Wind direction at 10-m level of Station A111
11	2	4	°	Wind direction at 10-m level of Station A112
12	2	5	°	Wind direction at 10-m level of Station A113
			Micrometeorological Data	
13	2	6	C	Temperature at 2-m level of Micromet, Station A114 and Station A115
14	2	7	C	Temperature at 4-m level of Micromet
15	3	1	C	Temperature at 8-m level of Micromet and Station A114
16	3	2	C	Temperature at 16-m level of Micromet
17	3	3	C	Temperature at 30-m level of Micromet and Station A115
18	3	4	m/s	u component of wind velocity at 2-m level of Micromet
19	3	5	m/s	u component of wind velocity at 4-m level of Micromet
20	3	6	m/s	u component of wind velocity at 8-m level of Micromet
21	3	7	m/s	u component of wind velocity at 16-m level of Micromet
22	4	1	m/s	u component of wind velocity at 30-m level of Micromet
23	4	2	m/s	v component of wind velocity at 2-m level of Micromet
24	4	3	m/s	v component of wind velocity at 4-m level of Micromet
25	4	4	m/s	v component of wind velocity at 8-m level of Micromet
26	4	5	m/s	v component of wind velocity at 16-m level of Micromet
27	4	6	m/s	v component of wind velocity at 30-m level of Micromet
28	4	7	m/s	w component of wind velocity at 2-m level of Micromet
29	5	1	m/s	w component of wind velocity at 4-m level of Micromet
30	5	2	m/s	w component of wind velocity at 8-m level of Micromet

31	5	3	m/s	w component of wind velocity at 16-m level of Micromet
30	5	4	m/s	w component of wind velocity at 30-m level of Micromet
33	5	5	m/s	Wind speed – top laser
34	5	6	m/s	Wind speed – middle laser
35	5	7	m/s	Wind speed – bottom laser

Bad data were indicated by placing the letter "x" in the column after the reported reading.

SAMPLE RAW DATA RECORD FOR STATIONS A111-A114

```
870921. 141000.    1.74    1.97    4.52    7.16    5.65
  10.71   12.60  304.33  306.49  271.03   38.56   38.13
  37.96   37.82   37.63   -1.37   -0.84   -0.90   -0.70
  -1.18    0.07    0.10    0.30   -0.10    0.35    0.06
  -0.06   -0.53   -1.34   -0.51   -1.96    1.55   -2.27
870921. 141001.    1.60    1.96    4.90    7.26    5.65
  13.27   17.86  306.63  305.28  270.63   38.56   38.14
  37.96   37.82   37.63   -1.56   -0.74   -0.84   -0.60
  -1.21   -0.02    0.13    0.19   -0.10    0.36   -0.10
  -0.15   -0.53   -0.97   -0.24   -1.51    1.39   -2.48
870921. 141002.    1.49    1.89    5.39    7.21    5.60
  13.27   16.11  306.63  304.20  268.06   38.58   38.16
  37.98   37.84   37.64   -1.60   -0.69   -0.85   -0.50
  -1.39   -0.06    0.19    0.04   -0.13    0.57   -0.33
  -0.36   -0.37   -0.69    0.13   -1.55    1.31   -2.21
```

APPENDIX B: REDUCED DATA FILES - NAMING CONVENTION AND FORMAT

B.1 FILE NAMING CONVENTION

All file names are of the form

StationName.JulianDay

where StationName represents the station name (e.g., A101 - A115) and JulianDay represents the corresponding Julian day (e.g., 264 - 280). For example, A103.270 contains the data from station A103 for Julian day 270 (September 27, 1987).

The processed database consists of 238 files containing the data of stations A101 - A114 for the 17 days between Julian day 264 and Julian day 280, inclusively. The data base also contains three additional files for station A109 covering Julian days 261, 262, and 263. Thus, the total processed data base contains 241 individual data files. The size of each of these data files is 89280 bytes.

B.2 DATA FORMAT

Columns	Units	Measurement
1-2	year	year (i.e., 87)
3		colon
4-6	day	Julian Day
7		colon
8-9	hour	Hour (24-hr format)
10		colon
11-12	minute	Minute
13		blank
14-19	m/s	10-m Wind Speed (Arithmetic Mean)
20		blank
21-26	m/s	10-m Wind Speed (Vector Sum)
27		blank
28-33	° E of N	10-m Wind Direction (Vector Sum)
34		blank
35-40	°	10-m Wind Direction (Standard Deviation)
41		blank
42-47	C	10-m Temperature
48		blank
49-54	C	2-m Temperature
55		blank
56-61	C	Soil Temperature

B.3 SAMPLE REDUCED DATA RECORD FOR STATION A101

```
87:266:00:00 +0.947 +0.940 +161.5 +6.726 +20.89 +18.34 +17.49
87:266:00:01 +0.997 +0.992 +145.6 +5.466 +20.73 +19.03 +17.47
87:266:00:02 +1.170 +1.149 +143.5 +10.84 +20.80 +19.74 +17.45
87:266:00:03 +1.033 +0.994 +117.8 +15.86 +20.83 +19.82 +17.42
87:266:00:04 +0.926 +0.905 +100.5 +12.02 +20.90 +19.69 +17.41
87:266:00:05 +1.224 +1.205 +122.4 +10.12 +20.90 +19.70 +17.39
87:266:00:06 +1.146 +1.116 +111.8 +13.02 +20.85 +19.66 +17.37
87:266:00:07 +1.219 +1.199 +112.8 +10.25 +20.81 +18.76 +17.36
87:266:00:08 +1.252 +1.213 +104.6 +14.26 +20.92 +19.30 +17.34
```

87:266:00:09	+1.350	+1.298	+095.3	+15.85	+21.06	+19.66	+17.32
87:266:00:10	+1.314	+1.285	+097.3	+12.13	+21.00	+19.74	+17.31
87:266:00:11	+1.480	+1.451	+102.4	+11.43	+21.01	+19.50	+17.29
87:266:00:12	+1.385	+1.357	+110.0	+11.52	+20.93	+19.56	+17.28
87:266:00:13	+1.398	+1.356	+124.4	+14.19	+20.95	+19.95	+17.27
87:266:00:14	+1.379	+1.314	+127.8	+17.60	+20.94	+19.56	+17.25
87:266:00:15	+1.223	+1.186	+113.1	+13.96	+20.92	+19.61	+17.24
87:266:00:16	+0.894	+0.871	+116.6	+12.96	+20.94	+19.19	+17.23
87:266:00:17	+0.901	+0.878	+128.4	+13.09	+20.90	+19.17	+17.21
87:266:00:18	+1.354	+1.338	+135.9	+08.88	+20.92	+19.43	+17.19
87:266:00:19	+1.268	+1.257	+143.8	+07.30	+21.06	+19.52	+17.18

APPENDIX C: FORMAT AND SAMPLE OF TIME-PERIOD SELECTED DATA

C.1 FORMAT OF SELECTED DATA

FOR EACH MINUTE:

Columns	Units	Measurement
1-2	year	Year (i.e. 87)
3		colon
4-6	day	Julian Day
7		colon
8-9	hour	Hour of Day
10		colon
11-12	minute	Minute of Hour

FOR EACH STATION AT EACH MINUTE:

Columns	Units	Measurement
1-2		blank
3-6		Station Name (e.g., a101)
7		blank
8-13	m/s	10-m Wind Speed (Arithmetic Mean)
14		blank
15-20	m/s	10-m Wind Speed (Vector Sum)
21		blank
22-27	°	10-m Wind Direction (Vector Sum)
28		blank
29-34	°	10-m Wind Direction (Standard Deviation)
35		blank
36-41	C	10-m Temperature (8-m for A114 and 30-m for A115)
42		blank
43-48	C	2-m Temperature
49		blank
50-55	C	Soil Temperature

C.2 SAMPLE TIME-PERIOD SELECTED DATA RECORD

```
87:270:05:44
  a101 +1.671 +1.667 +109.3 +4.078 +10.57 +08.12 +6.781
  a102 +0.464 +0.462 +082.3 +5.165 +10.07 +07.65 +4.363
  a103 +3.287 +3.255 +073.6 +07.87 +11.79 -99999 -99999
  a104 +3.404 +3.395 +54.26 +4.350 +12.21 -99999 -99999
  a105 +1.635 +1.625 +108.2 +6.472 +16.16 +15.30 +11.75
  a106 +2.783 +2.772 +101.6 +5.166 +11.69 +10.34 +11.42
  a107 +2.325 +2.287 +153.3 +10.40 +10.89 +09.57 +08.29
  a108 +2.065 +2.035 +100.1 +09.85 +10.31 +08.45 +10.51
  a109   +0.1   +0.1 -99999    +0.  +19.7  +18.9  +11.6
  a110 +1.425 +1.414 +160.6 +07.19 +18.48 +16.94 +13.42
  a111 +3.234 +3.230 +127.0 +2.854 -99999 -99999 -99999
  a112 +2.793 +2.776 +169.6 +6.780 -99999 -99999 -99999
  a113 +2.485 +2.467 +71.96 +7.050 -99999 -99999 -99999
```

a114	+1.136	+1.095	+88.40	+16.08	+9.400	+7.536	-99999
a115	+1.188	+1.153	+25.25	+14.38	+11.39	+7.536	-99999
87:270:05:45							
a101	+1.587	+1.579	+113.0	+5.583	+10.70	+08.40	+6.766
a102	+0.602	+0.599	+091.1	+5.747	+09.92	+08.28	+4.346
a103	+3.287	+3.231	+082.0	+10.53	+11.79	-99999	-99999
a104	+4.485	+4.469	+53.22	+4.892	+12.00	-99999	-99999
a105	+1.633	+1.622	+109.7	+6.761	+16.26	+15.11	+11.75
a106	+2.398	+2.387	+097.8	+5.247	+11.51	+11.02	+11.42
a107	+1.788	+1.745	+153.5	+12.63	+10.89	+09.44	+08.31
a108	+1.911	+1.898	+095.4	+6.812	+1[illegible]04	+08.46	+10.50
a109	+0.0	+0.0	-99999	+0.	+19.7	+18.9	+11.6
a110	+1.502	+1.483	+153.7	+09.22	+18.19	+16.90	+13.43
a111	+3.228	+3.219	+143.3	+4.112	-99999	-99999	-99999
a112	+2.915	+2.910	+169.4	+3.401	-99999	-99999	-99999
a113	+2.529	+2.518	+81.08	+5.372	-99999	-99999	-99999
a114	+1.208	+1.202	+105.4	+5.685	+9.306	+8.151	-99999
a115	+1.671	+1.668	+62.63	+3.101	+11.48	+8.151	-99999
87:270:05:46							
a101	+1.308	+1.273	+115.6	+13.29	+11.04	+08.14	+6.753
a102	+0.729	+0.674	+117.3	+22.31	+10.09	+08.79	+4.336
a103	+3.327	+3.300	+075.7	+07.24	+11.76	-99999	-99999
a104	+3.863	+3.854	+56.65	+3.876	+11.84	-99999	-99999
a105	+1.606	+1.592	+121.9	+07.68	+15.96	+14.99	+11.72
a106	+2.438	+2.416	+101.9	+07.66	+11.63	+11.33	+11.42
a107	+1.665	+1.627	+164.2	+12.15	+11.13	+09.52	+08.32
a108	+2.045	+2.033	+094.1	+6.112	+09.79	+08.45	+10.48
a109	+0.2	+0.2	-99999	+0.	+19.6	+18.8	+11.5
a110	+1.529	+1.523	+140.7	+4.981	+17.99	+16.68	+13.44
a111	+3.130	+3.125	+139.2	+3.079	-99999	-99999	-99999
a112	+2.901	+2.896	+172.1	+3.201	-99999	-99999	-99999
a113	+2.396	+2.386	+83.42	+5.109	-99999	-99999	-99999
a114	+1.042	+0.970	+129.7	+21.50	+9.517	+8.664	-99999
a115	+1.922	+1.871	+54.06	+13.45	+11.97	+8.664	-99999
87:270:05:47							
a101	+1.324	+1.311	+134.3	+07.96	+11.21	+08.18	+6.737
a102	+0.520	+0.514	+181.5	+08.62	+10.44	+09.10	+4.328
a103	+3.287	+3.246	+68.88	+08.96	+11.75	-99999	-99999
a104	+3.544	+3.514	+56.20	+07.40	+11.96	-99999	-99999
a105	+1.784	+1.781	+124.9	+3.568	+16.34	+15.18	+11.70
a106	+2.409	+2.390	+101.8	+07.15	+11.51	+11.25	+11.42
a107	+1.472	+1.358	+162.0	+22.48	+11.32	+09.34	+08.33
a108	+2.205	+2.196	+102.7	+4.917	+09.92	+08.42	+10.46
a109	+0.4	+0.4	-99999	+0.	+19.6	+18.8	+11.5
a110	+1.367	+1.362	+133.3	+4.576	+18.04	+16.65	+13.44
a111	+2.840	+2.834	+148.3	+3.867	-99999	-99999	-99999
a112	+2.951	+2.947	+173.6	+2.928	-99999	-99999	-99999
a113	+2.319	+2.310	+79.58	+4.975	-99999	-99999	-99999
a114	+0.600	+0.511	+184.9	+30.08	+9.815	+8.942	-99999
a115	+1.989	+1.973	+41.58	+7.120	+12.46	+8.942	-99999

APPENDIX D: RAW DATA FILES FOR STATIONS A101 - A110 AS CONTAINED ON ORIGINAL FLOPPY DISKS

STATION	ORIGINAL FILE NAME	FILE SIZE (BYTES)
A101	k87-1083.265	265913
A101	k87-1083.267	260839
A101	k87-1083.268	253051
A101	k87-1083.270	254998
A101	k87-1083.271	259010
A101	k87-1083.273	342672
A101	k87-1083.275	269630
A101	k87-1083.276	244378
A101	k87-1083.278	342672
A101	k87-1083.280	121009
A102	k87-1079.030	81538
A102	k87-1079.264	176720
A102	k87-1079.265	256119
A102	k87-1079.267	254290
A102	k87-1079.268	259600
A102	k87-1079.270	242903
A102	k87-1079.271	271105
A102	k87-1079.273	342672
A102	k87-1079.275	264792
A102	k87-1079.276	249216
A102	k87-1079.278	342672
A102	k87-1079.280	117351
A103	k87-a103.268	194446
A103	k87-a103.270	90912
A103	k87-a103.272	196099
A103	k87-a103.274	246698
A103	k87-a103.276	25012
A104	k87-a104.265	255224
A104	k87-a104.267	176935
A104	k87-a104.269	209113
A104	k87-a104.271	255312
A104	k87-a104.273	255312
A104	k87-a104.275	190301
A104	k87-a104.276	192579
A104	k87-a104.278	255312
A104	k87-a104.280	68619
A105	k87-1473.265	270515
A105	k87-1473.267	240248
A105	k87-1473.268	273760
A105	k87-1473.270	225852
A105	k87-1473.271	288038
A105	k87-1473.273	342672
A105	k87-1473.275	274173
A105	k87-1473.276	239717
A105	k87-1473.278	342672

STATION	ORIGINAL FILE NAME	FILE SIZE (BYTES)
A105	k87-1473.280	125198
A105	k87-3252.264	242175
A106	k87-1086.264	264261
A106	k87-1086.265	249983
A106	k87-1086.267	252756
A106	k87-1086.268	261252
A106	k87-1086.270	240720
A106	k87-1086.271	273288
A106	k87-1086.273	342672
A106	k87-1086.275	263081
A106	k87-1086.276	250809
A106	k87-1086.278	342672
A106	k87-1086.280	116289
A107	a107.264	94813
A107	a107.265	91037
A107	k87-1476.265	251517
A107	k87-1476.267	250868
A107	k87-1476.268	263140
A107	k87-1476.270	239540
A107	k87-1476.271	274468
A107	k87-1476.273	342672
A107	k87-1476.275	261311
A107	k87-1476.276	252697
A107	k87-1476.278	342672
A107	k87-1476.280	114991
A108	k87-1074.264	261544
A108	k87-1074.265	252697
A108	k87-1074.267	248803
A108	k87-1074.268	265087
A108	k87-1074.270	238124
A108	k87-1074.271	270633
A108	k87-1074.273	342672
A108	k87-1074.275	259895
A108	k87-1074.276	253995
A108	k87-1074.278	342672
A108	k87-1074.280	113870
A109	s009_1	345327
A109	s009_2	46256
A109	s109	343085
A109	s209	258833
A109	s309_1	345327
A109	s309_2	40592
A109	s409	108914
A109	s509	136054
A109	s609	294528
A109	s709	146025
A109	s809	214583
A110	k87-4089.264	254644
A110	k87-4089.265	259600
A110	k87-4089.267	257181
A110	k87-4089.268	256709

STATION	ORIGINAL FILE NAME	FILE SIZE (BYTES)
A110	k87-4089.270	245617
A110	k87-4089.271	268391
A110	k87-4089.273	342672
A110	k87-4089.275	267270
A110	k87-4089.276	246738
A110	k87-4089.278	342672
A110	k87-4089.280	119003

APPENDIX E: TIME PERIODS OF AVAILABLE DATA FOR STATIONS A111–A114

Tape	File	Times (Julian Day : Hour : Minute)
1	1	264:12:25 - 264:16:04
1	2	266:13:01 - 266:16:56
1	3	267:20:57 - 268:02:40
1	4	269:09:09 - 269:11:06
1	5	269:11:23 - 269:15:00
1	6	270:02:11 - 270:04:57
1	7	270:04:59 - 270:07:52
1	8	271:09:39 - 271:13:45
2	9	272:19:59 - 273:00:00
2	10	273:05:46 - 273:08:01
2	11	273:17:57 - 273:19:53
2	12	273:19:55 - 273:21:55
2	13	274:05:57 - 274:08:49
2	14	274:12:02 - 274:15:25
2	15	275:05:51 - 275:08:41
2	16	276:18:02 - 276:21:20
3	17	275:10:52 - 276:04:31
3	18	276:06:01 - 276:11:00

APPENDIX F: BAD DATA RECORDS IN ORIGINAL FLOPPY FILES

STATION	FILE	LINE NO(S).	PROBLEM / ACTION TAKEN
A102	k87-1079.264	2983	Faulty second line for 265:03:19; ignored
A103	k87-a103.264	1	Uninterpretable data fragment
A103	k87-a103.270	817	Uninterpretable data fragment
A103	k87-a103.276	420	Faulty second line for 276:15:23; filled out using missing data code
A103	k87-a103.276	517	Faulty second line for 276:16:14
A104	k87-a104.269	1	Uninterpretable data fragment
A105	k87-3252.264	4099	Uninterpretable data fragment (last line of file)
A108	k87-1074.264	4222	Uninterpretable data fragment
A109	s109	2010-2015	Uninterpretable data records

APPENDIX G: MISSING AND REPEATED TIME PERIODS IN ORIGINAL FLOPPY DATA FILES

STATION	TIME PERIOD	DURATION	PROBLEM/ACTION TAKEN
A101	264:00:00-265:10:44	2085	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A101	268:12:32-268:12:32	1	Missing Time Period Between Files k87-1083.267 and k87-1083.268; Filled Out with Missing Data Records
A101	280:16:57-280:23:59	423	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A102	264:00:00-264:11:23	684	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A102	264:11:28-264:11:29	2	Repeated Time Period; Data Appear Twice in File k87-1079.264 with Different Data Values (see further discussion below)**
A102	264:20:40-264:03:19	400	Repeated Time Period; Data Appear Twice in File k87-1079.264; Exact Duplication - One Set Eliminated
A102	265:05:20-265:12:03	404	Missing Time Period in File k87-1079.264 Possibly Due to Bad Block on Floppy; Filled Out with Missing Data Records
A102	268:11:37-268:11:37	1	Missing Time Period Between Files k87-1079.267 and k87-1079.268; Filled Out with Missing Data Records
A102	280:16:26-280:23:59	454	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A103	264:00:00-268:09:35	6336	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A103	268:10:33-268:12:24	112	Missing Time Period in File k87-a103.268; Filled Out with Missing Data Records
A103	270:06:46-270:07:42	57	Missing Time Period in File k87-a103.270; Filled Out with Missing Data Records

A103	270:18:03-272:11:08	2466	Missing Time Period Between Files k87-a103.270 and k87-a103.272; Filled Out with Missing Data Records
A103	275:22:24-276:11:55	812	Missing Time Period Between Files k87-a103.274 and k87-a103.276; Filled Out with Missing Data Records
A103	276:15:23-276:15:23	1	Bad Channel ID; Channel ID Ignored - Data Used
A103	276:16:14-276:16:14	1	Incomplete Data Record; Filled Out with Missing Data Code
A103	276:16:38-280:23:59	6202	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A104	264:00:00-265:00:00	1441	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A104	265:13:31-265:13:31	1	Missing Time Period in File k87-a104.265; Filled Out with Missing Data Records
A104	268:09:17-269:08:42	1406	Missing Time Period Between Files k87-a104.267 and k87-a104.269; Filled Out with Missing Data Records
A104	276:11:48-276:11:48	1	Missing Time Period Between Files k87-a104.275 and k87-a104.276; Filled Out with Missing Data Records
A104	280:10:55-280:11:48	54	Repeated Time Period; Data Appears Twice in File k87-a104.280; Exact Duplication - One Set Eliminated
A104	280:12:01-280:23:59	719	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A105	264:00:00-265:09:51	2032	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A105	265:09:52-265:10:01	10	Missing Time Period in File k87-3252.264; Filled Out with Missing Data Records
A105	265:10:05-265:10:05	1	Missing Time Period Between Files k87-3252.264 and k87-1423.265; Filled Out with Missing Data Records
A105	271:07:38-271:07:38	1	Missing Time Period Between Files k87-1423.270 and k87-1423.271; Filled Out with Missing Data Records
A105	276:14:25-276:14:25	1	Missing Time Period in File k87-1423.276; Filled Out with Missing Data Records

A105	280:17:32-280:23:59	388	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A106	264.11:07-264:11:09	3	Repeated Time Period; Data Appear Twice in File k87-1086.264 with Different Data Values (see further discussion below)**
A106	265:12:58-265:12:58	1	Missing Time Period Between Files k87-1086.264 and k87-1086.265; Filled Out with Missing Data Records
A106	276:12:51-276:12:51	1	Missing Time Period Between Files k87-1086.275 and k87-1086.276; Filled Out with Missing Data Records
A106	280:16:17-280:23:59	463	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A107	264:00:00-264:10:42	643	Missing Time Period at Beginning of Tests; Filled Out with Missing Data Records
A107	265:12:45-265:12:45	1	Missing Time Period Between Files a107.265 and k87-1476.265; Filled Out with Missing Data Records
A107	280:16:06-280:23:59	474	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A108	264:10:14-264:10:15	2	Repeated Time Period; Data Appear Twice in File k87-1074.264 with Different Data Values (see further discussion below)**
A108	264:19:35-265:02:09	395	Repeated Time Period; Data Appear Twice in File k87-1074.264; Exact Duplication - One Set Eliminated
A108	265:04:14-265:04:14	1	Faulty Second Line; Filled Out With Missing Data Codes
A108	265:04:15-265:10:54	400	Missing Time Period in File k87-1074.264 Possibly Due to Bad Block on Floppy; Filled Out with Missing Data Records
A108	268:10:51-268:10:51	1	Missing Time Period Between Files k87-1074.267 and k87-1074.268; Filled Out with Missing Data Records
A108	271:09:21-271:10:04	44	Missing Time Period Between Files k87-1074.270 and k87-1074.271; Filled Out with Missing Data Records

A108	276:12:24-276:12:24	1	Missing Time Period Between Files k87-1074.275 and k87-1074.276; Filled Out with Missing Data Records
A108	280:15:57-280:23:59	483	Missing Time Period at End of Tests; Filled Out with Missing Data Records
A109	264:17:05-264:17:13	9	Repeated Time Period; Data Appear Twice in File S009_2; Exact Duplication One Set Eliminated
A109	265:03:06-265:03:07	2	Repeated Time Period; Data Appear Twice in File S109 with Different Data Values (see further discussion below)**
A109	265:09:53-265:09:53	1	Missing Time Period in File S109; Filled Out with Missing Data Records
A109	268:05:12-268:05:18	7	Repeated Time Period; Data Appear Twice in File S209; Exact Duplication - One Set Eliminated
A109	270:11:14-270:11:14	1	Repeated Time Period; Data Appear Twice in File S309; Exact Duplication - One Set Eliminated
A109	270:12:18-273:09:03	4126	Missing Time Period in File S409; Filled Out with Missing Data Records
A109	273:23:07-273:23:14	8	Repeated Time Period; Data Appear Twice in File S409; Exact Duplication - One Set Eliminated
A109	274:18:01-274:18:09	9	Repeated Time Period; Data Appear Twice in File S509; Exact Duplication - One Set Eliminated
A109	276:11:15-276:11:15	1	Repeated Time Period; Data Appear Twice in File S609; Exact Duplication - One Set Eliminated
A109	276:11:27-278:08:52	2726	Missing Time Period Between Files S609 and S709; Filled Out with Missing Data Records
A109	279:05:07-279:05:07	1	Repeated Time Period; Data Appear Twice in File S709; Exact Duplication - One Set Eliminated
A109	280:11:02-280:11:09	8	Repeated Time Period; Data Appear Twice in File S809; Exact Duplication - One Set Eliminated
A109	280:11:14-280:23:59	766	Missing Time Period at End of Tests; Filled Out with Missing Data Records

A110	265:11:37-265:11:38	2	Repeated Time Period; 11:37 Repeated In File k87-4089.264; 11:38 Appears in k87-4089.264 and k87-4089.265; Readings Differ (see further discussion below)**
A110	268:12:01-268:12:01	1	Missing Time Period Between Files k87-4089.267 and k87-4089.268; Filled Out with Missing Data Records
A110	280:16:40-280:23:59	440	Missing Time Period at End of Tests; Filled Out with Missing Data Records

** **Repeated Records with Differing Values**

STATION A102

RAW DATA:

01+0113.	02+0087.	03+0264.	04+1115.	05+30.46	06+31.52	07-6999.	08+3.117
09+3.109	10+256.2	11+4.123	12+36.92				
01+0113.	02+0087.	03+0264.	04+1116.	05+30.55	06+31.44	07-6999.	08+3.274
09+3.261	10+252.1	11+5.276	12+37.01				
01+0113.	02+0087.	03+0264.	04+1117.	05+30.49	06+31.54	07-6999.	08+3.287
09+3.275	10+250.7	11+4.806	12+37.10				
01+0113.	02+0087.	03+0264.	04+1118.	05+30.74	06+31.89	07-6999.	08+3.005
09+2.978	10+253.3	11+07.59	12+37.20				
01+0113.	02+0087.	03+0264.	04+1119.	05+30.57	06+31.39	07-6999.	08+3.257
09+3.211	10+256.6	11+09.69	12+37.29				
01+0113.	02+0087.	03+0264.	04+1120.	05+30.60	06+31.47	07-6999.	08+2.902
09+2.886	10+255.9	11+5.994	12+37.39				
01+0113.	02+0087.	03+0264.	04+1121.	05+30.84	06+31.37	07-6999.	08+2.702
09+2.668	10+237.0	11+09.07	12+37.47				
01+0113.	02+0087.	03+0264.	04+1122.	05+31.15	06+31.77	07-6999.	08+2.471
09+2.457	10+239.5	11+6.159	12+37.57				
01+0113.	02+0087.	03+0264.	04+1123.	05+31.21	06+32.02	07-6999.	08+2.727
09+2.708	10+240.8	11+6.835	12+37.68				
01+0113.	02+0087.	03+0264.	04+1124.	05+31.10	06+31.72	07-6999.	08+2.939
09+2.928	10+250.0	11+4.846	12+37.92	(deleted)			

END OF FILE k87-1079.030

BEGINNING OF FILE k87-1079.264

01+0113.	02+0087.	03+0264.	04+1124.	05+30.94	06+31.44	07-6999.	08+2.645
09+2.640	10+241.5	11+3.754	12+38.68	(kept)			
01+0113.	02+0087.	03+0264.	04+1125.	05+30.97	06+31.69	07-6999.	08+2.653
09+2.619	10+243.4	11+09.19	12+39.62				
01+0113.	02+0087.	03+0264.	04+1126.	05+31.30	06+32.20	07-6999.	08+2.825
09+2.800	10+240.6	11+07.54	12+41.07				
01+0113.	02+0087.	03+0264.	04+1127.	05+31.38	06+32.00	07-6999.	08+2.721
09+2.648	10+237.6	11+13.30	12+42.18				
01+0113.	02+0087.	03+0264.	04+1128.	05+31.59	06+32.13	07-6999.	08+2.930
09+2.834	10+239.9	11+14.69	12+43.06	(kept)			

01+0113.	02+0087.	03+0264.	04+1129.	05+31.75	06+32.23	07-6999.	08+2.840
09+2.780	10+238.7	11+11.75	12+43.65	(kept)			
01+0113.	02+0087.	03+0264.	04+1128.	05+31.32	06+31.66	07-6999.	08+2.333
09+2.312	10+230.3	11+07.75	12+44.04	(deleted)			
01+0113.	02+0087.	03+0264.	04+1129.	05+31.65	06+32.68	07-6999.	08+2.535
09+2.483	10+245.1	11+11.65	12+44.39	(deleted)			
01+0113.	02+0087.	03+0264.	04+1130.	05+31.76	06+32.30	07-6999.	08+2.733
09+2.712	10+237.8	11+07.13	12+44.89				
01+0113.	02+0087.	03+0264.	04+1131.	05+31.79	06+32.62	07-6999.	08+2.765
09+2.742	10+246.6	11+07.44	12+45.24				
01+0113.	02+0087.	03+0264.	04+1132.	05+32.01	06+32.65	07-6999.	08+2.472
09+2.436	10+245.1	11+09.72	12+45.55				
01+0113.	02+0087.	03+0264.	04+1133.	05+31.82	06+32.84	07-6999.	08+3.002
09+2.989	10+242.4	11+5.308	12+45.86				
01+0113.	02+0087.	03+0264.	04+1134.	05+31.26	06+32.44	07-6999.	08+3.398
09+3.369	10+249.1	11+07.44	12+46.05				
01+0113.	02+0087.	03+0264.	04+1135.	05+31.41	06+32.15	07-6999.	08+2.752
09+2.720	10+255.2	11+08.72	12+46.32				
01+0113.	02+0087.	03+0264.	04+1136.	05+31.57	06+32.39	07-6999.	08+2.895
09+2.878	10+251.8	11+6.087	12+46.67				

REDUCED DATA:

87:264:11:19	+3.257	+3.211	+256.6	+09.69	+30.57	+31.39	+37.29	
87:264:11:20	+2.902	+2.886	+255.9	+5.994	+30.60	+31.47	+37.39	
87:264:11:21	+2.702	+2.668	+237.0	+09.07	+30.84	+31.37	+37.47	
87:264:11:22	+2.471	+2.457	+239.5	+6.159	+31.15	+31.77	+37.57	
87:264:11:23	+2.727	+2.708	+240.8	+6.835	+31.21	+32.02	+37.68	
87:264:11:24	+2.645	+2.640	+241.5	+3.754	+30.94	+31.44	+38.68	(suspect)
87:264:11:25	+2.653	+2.619	+243.4	+09.19	+30.97	+31.69	+39.62	
87:264:11:26	+2.825	+2.800	+240.6	+07.54	+31.30	+32.20	+41.07	
87:264:11:27	+2.721	+2.648	+237.6	+13.30	+31.38	+32.00	+42.18	
87:264:11:28	+2.930	+2.834	+239.9	+14.69	+31.59	+32.13	+43.06	(suspect)
87:264:11:29	+2.840	+2.780	+238.7	+11.75	+31.75	+32.23	+43.65	(suspect)
87:264:11:30	+2.733	+2.712	+237.8	+07.13	+31.76	+32.30	+44.89	
87:264:11:31	+2.765	+2.742	+246.6	+07.44	+31.79	+32.62	+45.24	
87:264:11:32	+2.472	+2.436	+245.1	+09.72	+32.01	+32.65	+45.55	
87:264:11:33	+3.002	+2.989	+242.4	+5.308	+31.82	+32.84	+45.86	
87:264:11:34	+3.398	+3.369	+249.1	+07.44	+31.26	+32.44	+46.05	
87:264:11:35	+2.752	+2.720	+255.2	+08.72	+31.41	+32.15	+46.32	
87:264:11:36	+2.895	+2.878	+251.8	+6.087	+31.57	+32.39	+46.67	

STATION A106

RAW DATA:

01+0113.	02+0087.	03+0264.	04+1102.	05+30.80	06+31.49	07-6999.	08+3.041
09+2.949	10+263.7	11+14.09	12+36.04				
01+0113.	02+0087.	03+0264.	04+1103.	05+30.75	06+31.55	07-6999.	08+3.436
09+3.421	10+270.7	11+5.358	12+36.14				
01+0113.	02+0087.	03+0264.	04+1104.	05+30.60	06+31.58	07-6999.	08+3.229
09+3.186	10+258.4	11+09.40	12+36.24				
01+0113.	02+0087.	03+0264.	04+1105.	05+30.87	06+31.74	07-6999.	08+2.902
09+2.875	10+251.4	11+07.75	12+36.33				
01+0113.	02+0087.	03+0264.	04+1106.	05+30.95	06+32.00	07-6999.	08+2.936
09+2.894	10+248.6	11+09.66	12+36.42				
01+0113.	02+0087.	03+0264.	04+1107.	05+31.02	06+31.88	07-6999.	08+3.105

09+3.074	10+255.5	11+08.07	12+36.53	(kept)			
01+0113.	02+0087.	03+0264.	04+1108.	05+30.82	06+31.56	07-6999.	08+3.086
09+3.057	10+248.8	11+07.84	12+36.64	(kept)			
01+0113.	02+0087.	03+0264.	04+1109.	05+31.09	06+32.02	07-6999.	08+2.826
09+2.771	10+264.5	11+11.29	12+36.68	(kept)			
01+0113.	02+0087.	03+0264.	04+1107.	05+30.89	06+31.49	07-6999.	08+3.166
09+3.143	10+254.5	11+6.937	12+36.79..	(deleted)			
01+0113.	02+0087.	03+0264.	04+1108.	05+31.13	06+31.82	07-6999.	08+2.786
09+2.756	10+247.8	11+08.37	12+36.87..	(deleted)			
01+0113.	02+0087.	03+0264.	04+1109.	05+31.23	06+31.96	07-6999.	08+2.633
09+2.605	10+254.2	11+08.41	12+36.97..	(deleted)			
01+0113.	02+0087.	03+0264.	04+1110.	05+31.35	06+32.16	07-6999.	08+2.750
09+2.718	10+258.9	11+08.83	12+37.06				
01+0113.	02+0087.	03+0264.	04+1111.	05+31.18	06+31.92	07-6999.	08+2.976
09+2.954	10+258.4	11+07.03	12+37.18				
01+0113.	02+0087.	03+0264.	04+1112.	05+31.18	06+31.93	07-6999.	08+2.995
09+2.980	10+252.3	11+5.740	12+37.31				
01+0113.	02+0087.	03+0264.	04+1113.	05+31.19	06+32.29	07-6999.	08+3.205
09+3.188	10+250.1	11+5.867	12+37.40				
01+0113.	02+0087.	03+0264.	04+1114.	05+31.32	06+31.98	07-6999.	08+2.886
09+2.827	10+250.3	11+11.57	12+37.53				

REDUCED DATA:

87:264:11:02	+3.041	+2.949	+263.7	+14.09	+30.80	+31.49	+36.04	
87:264:11:03	+3.436	+3.421	+270.7	+5.358	+30.75	+31.55	+36.14	
87:264:11:04	+3.229	+3.186	+258.4	+09.40	+30.60	+31.58	+36.24	
87:264:11:05	+2.902	+2.875	+251.4	+07.75	+30.87	+31.74	+36.33	
87:264:11:06	+2.936	+2.894	+248.6	+09.66	+30.95	+32.00	+36.42	
87:264:11:07	+3.105	+3.074	+255.5	+08.07	+31.02	+31.88	+36.53	(suspect)
87:264:11:08	+3.086	+3.057	+248.8	+07.84	+30.82	+31.56	+36.64	(suspect)
87:264:11:09	+2.826	+2.771	+264.5	+11.29	+31.09	+32.02	+36.68	(suspect)
87:264:11:10	+2.750	+2.718	+258.9	+08.83	+31.35	+32.16	+37.06	
87:264:11:11	+2.976	+2.954	+258.4	+07.03	+31.18	+31.92	+37.18	
87:264:11:12	+2.995	+2.980	+252.3	+5.740	+31.18	+31.93	+37.31	
87:264:11:13	+3.205	+3.188	+250.1	+5.867	+31.19	+32.29	+37.40	
87:264:11:14	+2.886	+2.827	+250.3	+11.57	+31.32	+31.98	+37.53	
87:264:11:15	+3.059	+2.928	+261.0	+16.77	+31.54	+32.26	+37.65	
87:264:11:16	+3.660	+3.590	+255.8	+11.26	+31.05	+31.75	+37.81	
87:264:11:17	+2.631	+2.509	+239.4	+17.40	+31.58	+32.15	+37.91	
87:264:11:18	+3.544	+3.483	+258.1	+10.65	+31.39	+31.97	+38.00	
87:264:11:19	+2.821	+2.749	+231.1	+12.97	+31.44	+32.04	+38.10	

STATION A108

RAW DATA:

01+0113.	02+0087.	03+0264.	04+1006.	05+29.33	06+30.58	07-6999.	08+1.894
09+1.803	10+314.1	11+17.76	12+31.25				
01+0113.	02+0087.	03+0264.	04+1007.	05+29.33	06+30.40	07-6999.	08+2.015
09+1.977	10+316.6	11+11.16	12+31.38				
01+0113.	02+0087.	03+0264.	04+1008.	05+29.31	06+30.39	07-6999.	08+2.103
09+2.075	10+322.2	11+09.42	12+31.52				
01+0113.	02+0087.	03+0264.	04+1009.	05+29.92	06+30.98	07-6999.	08+1.131
09+1.062	10+312.2	11+19.96	12+31.64				
01+0113.	02+0087.	03+0264.	04+1010.	05+29.61	06+30.95	07-6999.	08+2.019
09+1.969	10+318.8	11+12.74	12+31.76				

01+0113.	02+0087.	03+0264.	04+1011.	05+29.44	06+30.65	07-6999.	08+2.003
09+1.952	10+313.1	11+12.91	12+31.89				
01+0113.	02+0087.	03+0264.	04+1012.	05+29.47	06+30.71	07-6999.	08+2.016
09+1.979	10+310.4	11+11.07	12+32.04				
01+0113.	02+0087.	03+0264.	04+1013.	05+29.57	06+30.61	07-6999.	08+1.979
09+1.938	10+311.3	11+11.57	12+32.18				
01+0113.	02+0087.	03+0264.	04+1014.	05+29.80	06+31.06	07-6999.	08+1.728
09+1.702	10+308.0	11+09.99	12+32.37	(kept)			
01+0113.	02+0087.	03+0264.	04+1015.	05+30.00	06+31.49	07-6999.	08+1.716
09+1.682	10+304.4	11+11.40	12+32.59	(kept)			
01+0113.	02+0087.	03+0264.	04+1014.	05+29.81	06+31.03	07-6999.	08+2.315
09+2.292	10+325.0	11+08.05	12+32.71	(deleted)			
01+0113.	02+0087.	03+0264.	04+1015.	05+29.92	06+31.44	07-6999.	08+2.139
09+2.098	10+314.4	11+11.17	12+32.82	(deleted)			
01+0113.	02+0087.	03+0264.	04+1016.	05+30.12	06+31.42	07-6999.	08+1.618
09+1.541	10+316.2	11+17.72	12+32.99				
01+0113.	02+0087.	03+0264.	04+1017.	05+30.13	06+31.21	07-6999.	08+2.113

REDUCED DATA:

87:264:10:04	+1.941	+1.873	+326.7	+15.17	+29.15	+30.34	+30.96	
87:264:10:05	+2.038	+1.946	+306.3	+17.29	+29.14	+30.50	+31.11	
87:264:10:06	+1.894	+1.803	+314.1	+17.76	+29.33	+30.58	+31.25	
87:264:10:07	+2.015	+1.977	+316.6	+11.16	+29.33	+30.40	+31.38	
87:264:10:08	+2.103	+2.075	+322.2	+09.42	+29.31	+30.39	+31.52	
87:264:10:09	+1.131	+1.062	+312.2	+19.96	+29.92	+30.98	+31.64	
87:264:10:10	+2.019	+1.969	+318.8	+12.74	+29.61	+30.95	+31.76	
87:264:10:11	+2.003	+1.952	+313.1	+12.91	+29.44	+30.65	+31.89	
87:264:10:12	+2.016	+1.979	+310.4	+11.07	+29.47	+30.71	+32.04	
87:264:10:13	+1.979	+1.938	+311.3	+11.57	+29.57	+30.61	+32.18	
87:264:10:14	+1.728	+1.702	+308.0	+09.99	+29.80	+31.06	+32.37	(suspect)
87:264:10:15	+1.716	+1.682	+304.4	+11.40	+30.00	+31.49	+32.59	(suspect)
87:264:10:16	+1.618	+1.541	+316.2	+17.72	+30.12	+31.42	+32.99	
87:264:10:17	+2.113	+2.067	+306.8	+11.90	+30.13	+31.21	+33.17	
87:264:10:18	+1.720	+1.652	+313.0	+16.02	+30.33	+31.28	+33.33	
87:264:10:19	+2.247	+2.210	+305.7	+10.43	+30.24	+31.07	+33.49	
87:264:10:20	+2.471	+2.385	+300.7	+15.09	+30.29	+31.24	+33.64	
87:264:10:21	+2.299	+2.190	+301.5	+17.60	+30.25	+31.27	+33.74	
87:264:10:22	+2.616	+2.584	+312.1	+09.02	+30.14	+31.33	+33.84	
87:264:10:23	+2.026	+1.906	+320.8	+19.72	+30.42	+31.51	+33.94	

STATION A109

RAW DATA:

01+0000.	02+0087.	03+0265	04+0303	05 +32.7	06 +31.5	07+6777.	08 +2.3
09 +2.3	10 +77.	11 +13.	12 +20.9				
01+0000.	02+0087.	03+0265	04+0304	05 +32.3	06 +31.3	07+6777.	08 +1.7
09 +1.7	10 +60.	11 +20.	12 +20.9				
01+0000.	02+0087.	03+0265	04+0305	05 +31.9	06 +31.1	07+6777.	08 +0.9
09 +0.9	10 +14.	11 +35.	12 +20.9				
01+0000.	02+0087.	03+0265	04+0306	05 +31.7	06 +30.9	07+6777.	08 +1.2
09 +1.2	10 +294.	11 +25.	12 +20.9	(kept)			
01+0000.	02+0087.	03+0265	04+0307	05 +30.9	06 +30.7	07+6777.	08 +1.2
09 +1.2	10 +273.	11 +8.	12 +20.9	(kept)			
01+0000.	02+0087.	03+0265	04+0308	05 +30.8	06 +30.4	07+6777.	08 +1.2
09 +1.2	10 +272.	11 +14.	12 +20.8				

01+0000.	02+0087.	03+0265	04+0309	05 +30.8	06 +30.2	07+6777.	08 +1.1
09 +1.1	10 +275.	11 +19.	12 +20.8				
01+0000.	02+0087.	03+0265	04+0310	05 +31.7	06 +30.1	07+6777.	08 +0.6
09 +0.6	10 +269.	11 +30.	12 +20.8				
			.				
			.				
			.				
01+0000.	02+0087.	03+0265	04+0952	05 +28.6	06 +28.9	07+6777.	08 +1.4
09 +1.4	10 +261.	11 +7.	12 +34.1				
01+0000.	02+0087.	03+087	04+952	05 +28.6	06 +28.9	07+6777.	08 +1.6
09 +1.6	10 +260.	11 +2.	12 +34.3	(bad record)			
01+0000.	02+0087.	03+087	04+305	05 +28.6	06 +28.9	07+6777.	08 +1.4
09 +1.4	10 +258.	11 +2.	12 +34.3	(bad record)			
01+0000.	02+0087.	03+087	04+306	05 +28.6	06 +28.9	07+6777.	08 +1.2
09 +1.2	10 +264.	11 +11.	12 +34.3	(bad record)			
01+0000.	02+0087.	03+0265	04+0306	05 +28.3	06 +28.8	07+6777.	08 +0.9
09 +0.9	10 +259.	11 +14.	12 +34.4	(deleted)			
01+0000.	02+0087.	03+0265	04+0307	05 +28.3	06 +28.8	07+6777.	08 +1.0
09 +1.0	10 +263.	11 +12.	12 +34.4	(deleted)			
01+0000.	02+0087.	03+0265	04+0954	05 +28.4	06 +28.9	07+6777.	08 +0.9
09 +0.9	10 +268.	11 +10.	12 +34.6				
01+0000.	02+0087.	03+0265	04+0955	05 +28.4	06 +28.9	07+6777.	08 +1.3

REDUCED DATA:

87:265:03:01	+2.5	+2.5	+80.	+9.	+33.5	+31.8	+21.0	
87:265:03:02	+2.6	+2.6	+79.	+9.	+33.0	+31.7	+20.9	
87:265:03:03	+2.3	+2.3	+77.	+13.	+32.7	+31.5	+20.9	
87:265:03:04	+1.7	+1.7	+60.	+20.	+32.3	+31.3	+20.9	
87:265:03:05	+0.9	+0.9	+14.	+35.	+31.9	+31.1	+20.9	
87:265:03:06	+1.2	+1.2	+294.	+25.	+31.7	+30.9	+20.9	(suspect)
87:265:03:07	+1.2	+1.2	+273.	+8.	+30.9	+30.7	+20.9	(suspect)
87:265:03:08	+1.2	+1.2	+272.	+14.	+30.8	+30.4	+20.8	
87:265:03:09	+1.1	+1.1	+275.	+19.	+30.8	+30.2	+20.8	

STATION A110

RAW DATA:

01+0113.	02+0087.	03+0265.	04+1134.	05+28.35	06+29.08	07-33.66	08+2.308
09+2.202	10+323.3	11+17.41	12+44.40				
01+0113.	02+0087.	03+0265.	04+1135.	05+28.61	06+29.62	07-33.71	08+2.351
09+2.276	10+331.6	11+14.51	12+44.47				
01+0113.	02+0087.	03+0265.	04+1136.	05+28.16	06+29.16	07-33.83	08+2.962
09+2.922	10+322.9	11+09.43	12+44.55				
01+0113.	02+0087.	03+0265.	04+1137.	05+28.51	06+29.58	07-33.78	08+2.633
09+2.536	10+330.0	11+15.53	12+44.63	(kept)			
01+0113.	02+0087.	03+0265.	04+1138.	05+28.01	06+29.23	07-33.92	08+2.888
09+2.863	10+327.1	11+07.62	12+44.70	(kept)			
01+0113.	02+0087.	03+0265.	04+1137.	05+27.99	06+29.05	07-34.05	08+2.107
09+2.105	10+332.3	11+2.411	12+44.75	(deleted)			
01+0113.	02+0087.	03+0265.	04+1138.	05+28.22	06+29.11	07-33.85	08+2.429
09+2.373	10+327.6	11+12.36	12+44.76	(deleted)			
01+0113.	02+0087.	03+0265.	04+1139.	05+28.25	06+29.43	07-33.93	08+2.505
09+2.471	10+336.1	11+09.44	12+44.80				
01+0113.	02+0087.	03+0265.	04+1140.	05+28.05	06+29.20	07-33.73	08+2.760

REDUCED DATA:

87:265:11:34	+2.308	+2.202	+323.3	+17.41	+28.35	+29.08	+44.40	
87:265:11:35	+2.351	+2.276	+331.6	+14.51	+28.61	+29.62	+44.47	
87:265:11:36	+2.962	+2.922	+322.9	+09.43	+28.16	+29.16	+44.55	
87:265:11:37	+2.633	+2.536	+330.0	+15.53	+28.51	+29.58	+44.63	(suspect)
87:265:11:38	+2.888	+2.863	+327.1	+07.62	+28.01	+29.23	+44.70	(suspect)
87:265:11:39	+2.505	+2.471	+336.1	+09.44	+28.25	+29.43	+44.80	

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