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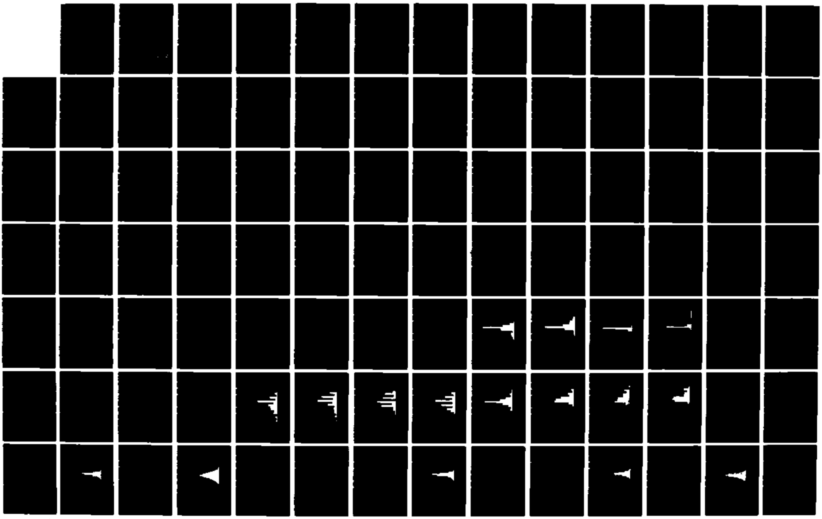

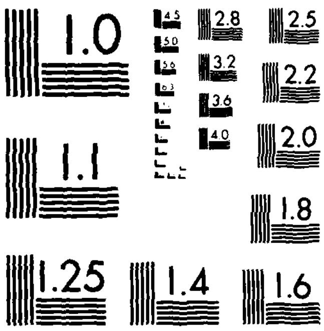

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Automated Weather Observing System (AWOS) Demonstration Program

Paul J. O'Brien et al.

Prepared By
FAA Technical Center
Atlantic City Airport, N.J. 08405

September 1984

Final Report

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Program Engineering and Maintenance Service
Washington, D.C. 20905

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16. Abstract

The Federal Aviation Administration conducted an operational demonstration of the Automated Weather Observing System (AWOS). Fourteen units were procured and installed at airports in 12 states, including two units in Alaska and two units in California. The demonstration units consist of commercially available equipment including sensors, processors, and auxiliary hardware. Sensors measure nine atmospheric variables: cloud height, visibility, wind speed, wind direction, barometric pressure, temperature, dew point, precipitation amount, and precipitation occurrence.

This report discusses the analyses and provides results, conclusions, and recommendations derived from source data for the period September 1983 through June 1984. Source data included pilot questionnaire responses, maintenance personnel failure logs, hourly AWOS observations, and official observations when available.

It was concluded that, in general, the performance of the system and all sensors at the 14 field sites was acceptable except for the ceilometer and precipitation sensors.

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EXECUTIVE SUMMARY

An operational demonstration of the Automated Weather Observing System (AWOS) was conducted by the Federal Aviation Administration at 14 airport installations in the contiguous United States and Alaska. The AWOS demonstration units employed were procured from two system manufacturers, WeatherMeasure and Artais, and consisted of commercially available equipment including sensors, processors, and auxiliary hardware. The sensors were used to detect and measure nine atmospheric parameters: cloud height, visibility, wind speed, wind direction, barometric pressure, temperature, dew point, precipitation occurrence, and precipitation amount. These data were then digitized, processed, synthesized into voice messages, and updated each minute. Access to the voice messages by pilots in flight was accomplished by very high frequency (VHF) omnidirectional range (VOR) or discrete VHF, and for preflight purposes, by telephone access.

This report discusses the analyses and provides results and conclusions derived from AWOS demonstration source data collected during the period September 1983 through June 1984. Source data included pilot questionnaire user responses, maintenance personnel failure logs, hourly AWOS observations, and official observations when available.

The primary measure of importance in the questionnaire responses was the pilots' rating of overall system performance. Based on a scale of 1 (poor) to 5 (excellent), the average pilot rating was 3.64, which represents an above average system rating. The system rating was highest (4.01) when pilots accessed AWOS by discrete VHF. Availability and currency of AWOS were the pilots' most favorable responses. In contrast, the primary unfavorable comments dealt with difficulties experienced by pilots in the synthesized voice message.

Failure log data were used as a basis for computations of cumulative mean-time-between-failure (MTBF) for the 10-month (7,200 hour) demonstration period. Following customary, widely accepted practices, overall system MTBF's were computed by dividing the respective aggregate operating times by the aggregate number of failures. The seven WeatherMeasure systems experienced 16 failures; whereas, the seven Artais systems experienced 184 failures. As a direct consequence, the system MTBF value for WeatherMeasure was greater than 3,000 hours and greater than 250 hours for Artais.

Failure log data were also used as a basis for computations of cumulative mean-time-to-repair (MTTR). Calculation of MTTR values was performed in all instances except where either no failure occurred, or where a failure occurred but was not resolved by the end of the demonstration period. Cumulative MTTR system values for WeatherMeasure ranged from less than 0.2 to greater than 2.0 hours, with the average for all sites being approximately 1.0 hours. Cumulative MTTR system values for Artais ranged from less than 0.3 to greater than 4.0 hours, with the average for all sites also being approximately 1.0 hours.

AWOS and official observations were compared to determine differences between AWOS measurements and corresponding collocated official observations. Based on this comparison, the performance of AWOS in detecting and reporting visibility, temperature, dew point, barometric pressure, wind direction, wind speed, and wind gust was acceptable. Performance in detecting and reporting the number of cloud layers, cloud coverage, and cloud height in the absence of precipitation was marginal to good. Cloud element detection and reporting during precipitation was unacceptable. Precipitation detection was also unacceptable.

INTRODUCTION

PURPOSE.

The purpose of the Automated Weather Observing System (AWOS) Demonstration Program was to:

1. Demonstrate to pilots, airport operators, air traffic control (ATC) and maintenance personnel that by using commercially available equipment, the system engineering concept of AWOS would enable the required weather parameters to be reported to the pilot in near real-time in an accurate and consistent manner.

2. Closely monitor each AWOS demonstration unit at designated field sites and collect and analyze data pertinent to performance, reliability, and maintainability.

3. Solicit and document user comments on the performance and usefulness of AWOS information.

BACKGROUND.

The AWOS Demonstration Program entailed the procurement, installation, and 1-year trial operation of commercially available units at 14 airports. The trial operation period of 1 year consisted of a 2-month "burn-in" or "debugging" period and a 10-month "useful life" period. The burn-in period was used to establish the Data Acquisition System and allowed typically high equipment failure rates to stabilize. Consequently, data were collected only over the 10-month period from September 1, 1983 to June 30, 1984. There were two system contractors: Artais, Incorporated of Columbus, Ohio, and WeatherMeasure (Qualimetrics), Incorporated of Sacramento, California. Each contractor built and installed seven AWOS units at the following locations.

Artais	WeatherMeasure
Bremerton, Washington	Keene, New Hampshire
Valdez, Alaska	Galena, Alaska
Dubuque, Iowa	Auburn, Alabama
Washington National, D.C.	Houston, Texas
Houghton, Michigan	San Luis Obispo, California
Houma, Louisiana	Muncie, Indiana
Santa Fe, New Mexico	Palm Springs, California

During the course of the data collection period, several types of data were required by the Federal Aviation Administration (FAA) Technical Center. These data were used to determine user acceptance, to detect equipment problems, and to analyze system performance. The FAA Technical Center was responsible for the distribution, collection, and analysis of maintenance logs; the collection and analysis of pilot questionnaires; and retrieval and analysis of digital data from each AWOS and official observation site.

TABLE 3. PILOT QUESTIONNAIRE RESPONSIVENESS DISTRIBUTION

	Location	Count
1	AUO	20
2	HOU	28
3	EEN	55
4	MIE	32
5	PSP	24
6	SBP	52
7	GAI	1
8	DCA	29
9	DBQ	50
10	HUM	36
11	CMX	27
12	PWT	29
13	SAF	27
14	VDZ	6

3. AWOS Favorable Responses. A tabulation was made of all questionnaires indicating favorable AWOS responses. Classification categories were established to include repetitive type responses as well as to accommodate grouping of similarity in the subjective type comments that occurred. A count of the responses by classification category was then performed and presented on a horizontal bar diagram. The total of 525 favorable responses exceeds the number of questionnaires analyzed because some pilots listed more than one favorable comment. The results of the analysis are shown in figure 9. This figure indicates that "Availability" and "Currency" are the major categories of favorable responses.

4. AWOS Unfavorable Responses. Analysis of the unfavorable AWOS responses to the pilot questionnaire followed the same basic procedural scheme as that performed for the favorable responses. The graphic results of this analysis are illustrated in figure 10. As noted, the dominant unfavorable response category is "Voice Hard to Understand." Sixty-nine (25.4 percent) of the 272 total unfavorable pilot comments were included in this category. Thirty-five pilots questioned the "Accuracy" of the information given by AWOS.

Examination of other voice related categories in figure 10 reveals an additional 51 unfavorable responses in the "Voice too Slow" category (27) and in the "Voice Poor/Weak" category (24). Table 4 provides the results of the unfavorable voice comment distribution obtained for each system contractor. A comparison of the WeatherMeasure total of 86 with the Artais total of 34 indicates approximately two and one-half times the number of unfavorable voice comments generated by pilots using the WeatherMeasure System as opposed to the Artais System. However, it should be noted that the WeatherMeasure site at Houston which uses a Doppler VOR, produced an excessive number of these unfavorable voice comments. Of the 28 total responses received from Houston, 19 listed an unfavorable voice comment. This represents 68 percent of the pilots who evaluated Houston AWOS. The reason for the low rating at Houston was due to the VOR's 10 kilohertz (kHz) side-band modulation which masked the voice message. Houston was the only site to use Doppler VOR and the side-band modulation is characteristic of this type VOR.

TABLE 2. AWOS FUNCTIONAL REQUIREMENTS

Visibility	
Range	<1/4 to 5+ miles
Resolution	<1/4, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 2, 2 1/2, 3, 3 1/2 4, 5, 5+
Accuracy	± one reportable increment 90% of data points
Cloud Height	
Range	100 to 5,000 ft (visibility 3 miles no precipitation) 100 to 3,000 ft (50% hits) in moderate rain
Accuracy	±100 ft to 1500 ft ±10% from 1,500 ft to 5,000 ft
Temperature	
Range	-60° F to 130° F
Accuracy	1° F (-40° F to +120° F) 2° F (-60° F to -40° F, +120° F to 130° F)
Dew Point	
Range	-30° F to 90° F
Accuracy	2° F (30° F to 90° F 100% to 15% RH) 3° F (-10° F to 30° F, 95% to 15% RH) 4° F (-30° F to -10° F, 95% to 15% RH)
Wind Speed	
Range	0-100 knots
Accuracy	2 knots (calm to 20 knots) 10% (20 to 100 knots) (2-minute average)
Wind Direction	
Range	0°-360°
Accuracy	10° (2-minute average)
Wind Gust	Same as wind speed accuracy, but with 5-second average
Altimeter Setting	
Range	28-32 in Hg (-500 to 10,000 feet m.s.l.)
Accuracy	0.01 in Hg
Precipitation Occurrence	
Accuracy	0.01 inch of precipitation in 10 minutes (the IFB incorrectly specifies 0.05 inches in 15 minutes)
Precipitation Quantity	
Accuracy	±0.02 inches for rates less than 1 inch/hour
Accumulation	Reported each 1, 6 and 24-hour totals

m.s.l. = mean sea level
Hg = inches of mercury

Performance, Failure, and Repair Logs were used for calculating values of mean-time-between failures (MTBF) and mean-time-to-repair (MTTR) for each system and each sensor. These forms were completed by the field technician and sent routinely to the Technical Center for cumulative compilations. The dedication of these technicians in the performance of their duties contributed significantly to the success of the demonstration program.

Hourly observations, a third source of data for analysis, were used to obtain a comparison between the official observation and the AWOS data. While this comparison has its obvious value, it must be recognized that the observation location and times may not be equal and the basic approach for obtaining parameters, such as visibility, are significantly different. These data sets were used to calculate differences in terms of mean values of the root-mean-square (rms) error, and to prepare time series plots of residual error, scattergrams, and relative and cumulative frequency histograms.

2. Functional Requirements. The AWOS functional requirements for each meteorological parameter are listed in table 2. All accuracies shown are rms values except visibility, cloud height, and precipitation occurrence. The balance of this report, particularly the section relating AWOS to the official observations, shows the degree of success in AWOS to meet these functional requirements.

DISCUSSION

PILOT QUESTIONNAIRE ANALYSIS.

1. General. During the 10-month period of September 1983 through June 1984, 456 pilot questionnaire forms were received. Thirty-six of these forms were rejected due to inadequacies and insufficient information. These included cases where the overall rating of system performance was omitted or the questionnaire did not appear to be filled out by a pilot. Also, four of the 420 acceptable questionnaires did not specify the site location. An analysis of the questionnaire survey was performed to determine the national responsiveness distribution of AWOS sites used by pilots. This analysis revealed that the highest response from pilots was at Keene (55), San Luis Obispo (52), and Dubuque (50); while the lowest were at Galena (1), and Valdez (6). Discussions with pilots at the AWOS locations revealed that pilot usage of the systems was much higher than indicated by the quantity of questionnaire responses. Table 3 shows the distribution of national responsiveness based on the 416 site-specific questionnaires.

2. Aircraft Type Used. "Type of Aircraft" data used were extracted from the questionnaires and tabularly recorded. An analysis was then made concerning the appropriate general aircraft type classification and a tally made of aircraft types by respective categories. A graphical depiction of the results is shown by the horizontal bar diagram in figure 8.

AIRWAYS FACILITIES
AUTOMATED WEATHER OBSERVING SYSTEM
DEMONSTRATION PROGRAM
PERFORMANCE, FAILURE, AND REPAIR LOG

LOCATION: ____________________

Failure #	Admin. Down Time		Log Down Time		Repair Actions					Time to Repair	Time to Restore
	Detect Time (a)	Prev Mt Time (i)	Travel Time (b)	Acquire Spare (e)	Time to Diagnose (c)	Time to Remove (d) Mod	Time to Repair (f)	Time to Reinstall (g)	Time to Verify (h)	c+d+f +g+h	Time to Repair +a+b+e
1											
2											
TOTALS											

	PROBLEM DESCRIPTION	PROBLEM SOLUTION
1		
2		

Send Forms To:
AWOS Demonstration Program ACT-110
FAA Technical Center
Atlantic City Airport, N. J. 08405

Technical Center Assistance:
Artais - Dennis Steelman -------- 482-5261
WeatherMeasure - Paul Quick ----- 482-4337
Met. Tech. - Warren Smith ------- 482-4341

FIGURE 7. AWOS DEMONSTRATION PROGRAM PERFORMANCE, FAILURE, AND REPAIR LOG

AUTOMATED WEATHER OBSERVING SYSTEM (AWOS) PILOT QUESTIONNAIRE

The Federal Aviation Administration is conducting a demonstration of the AWOS. Your comments are solicited. Please complete and mail a form each time you use the system. The demonstration will end July 31, 1984.

1. Where and when did you use AWOS? ______________________________
2. Your aircraft type? ____________________
3. Average flying hours/year? ________________
4. How did you get the information? VOR_____, NDB _____
   Special Designated Frequency _____, FSS Specialist _____
   ATC _____, Telephone (computer voice) _______
5. If you got the information by radio, how far from the radio or airport were you? ________ miles
6. Were you under IFR _____ or VFR _______ ?
7. Compare the AWOS Ceiling and Visibility Report with actual observations experienced during flight.
   ceiling reported ______ feet, actual observation ______ feet;
   visibility reported ________ miles, actual observation _______ miles.
8. Is this the first time you have responded to this survey? Yes ____ No _____
   For questions 9, 10, 11. Please do not repeat comments you have given on previous responses to this survey.
9. What did you like best about AWOS? ______________________________
   ____
   ____
   Least? ______________________________
   ____
   ____
10. Overall satisfaction. Score from 1 (poor) to 5 (excellent) ________
11. (OPTIONAL) Please feel free to comment further:
   ____
   ____
   ____
   ____
   ____

Thank you

CT FORM 7950-2 (10-83)

FIGURE 6. AWOS PILOT QUESTIONNAIRE

TABLE 1. DATA SUMMARY FOR AWOS VERSUS OFFICIAL COMPARISON ANALYSIS

AWOS			Official		Comparison Sample		
System	ID	Site Location	Agency	Hours	Period	Size N	dt
A	CMX	Houghton, Michigan	FAA	PT	12/14 - 06/30	2177	7.6
R	DBQ	Dubuque, Iowa	NWS	PT	12/13 - 06/21	1650	8.0
T	DCA	Washington, District of Columbia	CON	FT	09/15 - 06/30	3031	8.0
A	HUM	Houma, Louisiana	FAA	PT	12/02 - 06/30	1383	12.8
I	PWT	Bremerton, Washington	FBO	PT	02/07 - 06/30	173	10.6
S	SAF	Santa Fe, New Mexico	FAA	PT	06/13 - 06/29	117	8.3
	VDZ	Valdez, Alaska	CON	PT	12/15 - 06/26	740	8.5
W	EEN	Keene, New Hampshire	FBO	PT	09/13 - 06/30	901	7.7
X	GAL	Galena, Alaska	AWS	FT	12/14 - 06/30	2809	4.9
M	HOU	Houston, Texas	FAA	FT	09/16 - 06/30	4574	9.9
E	MIE	Muncie, Indiana	FAA	PT	09/14 - 06/30	1930	14.2
A	PSP	Palm Springs, California	FAA	PT	09/14 - 06/30	2919	13.4
S	SBP	San Luis Obispo, California	CON	PT	04/16 - 06/30	588	12.8

series of the raw data were plotted and visually inspected for anomalous data points which might have been undetected by the quality control and error-checking programs. Manual editing of the data bases was carried out based on the results of the quality control, error-checking, and plotting routines.

One special-purpose computer program was designed to carry out the numerical and statistical techniques used in the AWOS versus official analysis. The meteorological parameters compared were: (1) sky and ceiling parameters, (2) visibility, (3) temperature, (4) dew point temperature, (5) altimeter setting, (6) wind direction, (7) wind speed, (8) wind gust, and (9) precipitation occurrence. Two rules were adopted for the comparison. First, AWOS records were compared with corresponding official observations only when the time difference between them was within 15 minutes. Second, objectivity was maintained by comparing AWOS data only with collocated official data. As a result, the AWOS demonstration site at AUO was eliminated from this study, and only the collocated official data were used in the SBP comparison.

A summary of the AWOS and official data sets used in the comparison analysis is presented for 13 AWOS sites in table 1. In this table, N represents the number of paired hourly records compared and analyzed and t represents the average time difference between these paired records. A small sample size for PWT is a result of AWOS measurements being processed at the beginning of each hour, while the official observations are taken mostly on the clock half-hour. The small sample size for SAF is a result of communication problems between the AWOS site and the FAA Technical Center.

Data acquisition, processing, analysis, and plotting were accomplished on a Perkin-Elmer Multiprocessor System (model 3200 MPS) digital computer and Ramtek Graphic Display System (RM-9400 series) located at the FAA Technical Center's Aviation Weather Laboratory. The quality control, editing, and comparison analysis programs were written in extended Perkin-Elmer FORTRAN VII language.

TECHNICAL APPROACH.

1. Methods of Analysis. Three sources of data were used to evaluate AWOS with respect to the objectives stated in the "Purpose" section of this report. These sources consisted of pilot questionnaires (figure 6), Performance, Failure, and Repair Logs (figure 7), and data sets of AWOS and official observations which were discussed previously in the "Data Acquisition System" section of this report.

The pilot questionnaires were the primary means of assessing user acceptance of AWOS. The form was coordinated with and approved for distribution by the Office of Management and Budget (OMB). The forms were distributed to all AWOS sites and to accident and prevention groups of the FAA. The accident and prevention groups were particularly helpful in distributing these forms to the pilots by way of safety seminars which provided the means to introduce and explain AWOS to the users. Jeppesen Sandersen Incorporated was also helpful in the distribution of the pilot questionnaires by way of the "Jeppesen Briefing Bulletin."

Station ID	Time GMT	Date	Sky and Ceiling	Visibility (mi)	Temp (°F)	Dew (°F)	Alt (in Hg)	Dir (°)	Speed (kt)	Gust (kt)	Remarks
MIE	1345	1013	M5 OVC	5	45	M	974	020	10		
MIE	1445	1013	M7 OVC	4	45	M	978	310	12		
MIE	1545	1013	M7 BKN 12 OVC	3	45	M	980	290	10		
MIE	1605	1013	M8 OVC	21/2			981	280	12		
MIE	1745	1013	E10 OVC	6	47	M	981	270	12		
MIE	1845	1013	E15 BKN 25 OVC	7	46	M	983	270	13		
MIE	1945	1013	E15 BKN 25 OVC	7	47	M	983	270	14		BINOVC
MIE	2145	1013	18 SCT E40 BKN 200	9	49	M	985	270	14		
MIE	2245	1013	40 SCT	12	47	M	986	230	08		
MIE	2355	1014	CLR	12	43	M	987	200	08		
MIE	0045	1014	M45 BKN	8	43	M	990	200	13		
MIE	0145	1014	M30 OVC	8	42	M	992	280	10		
MIE	0245	1014	M15 OVC	21/2	41	M	993	230	15	25	Last

mi = Miles
M = Missing

FIGURE 5. EXAMPLE OF OFFICIAL OBSERVATIONS

Official weather data obtained by human observers at each AWOS site were also collected, processed, and archived each weekday at the FAA Technical Center. The observers at each airport were provided by either the NWS, Air Weather Service (AWS), FAA Flight Service Station (FSS), Fixed-Based Operator (FBO), or contracting activity. The hourly official weather observations are in surface aviation observation (SAO) format and consist of scheduled record observations (SA's), unscheduled special observations (SP's), and scheduled record observations that also qualify as special observations (RS's). An example of archived official weather observations and meteorological parameters is given in figure 5.

Official weather reports are either teletyped to the Weather Message Switching Center (WMSC) in Kansas City, Missouri; or transmitted to the National Meteorological Center (NMC) in Suitland, Maryland, over an Automation of Field Operations and Services (AFOS) system terminal. Official data for the AWOS sites were first acquired from these two national data bases by the MITRE Corporation in McLean, Virginia, and then transmitted by WATS line to the FAA Technical Center for decoding, archiving, and comparison with corresponding AWOS data.

The 14 AWOS sites, corresponding official observation sites, and their associated three-letter site identifiers are shown below:

AWOS Sites	Official Observation Sites
1. Galena (GAL)	1. Galena (PAG)
2. Valdez (VDZ)	2. Valdez (VDZ)
3. Dubuque (DBQ)	3. Dubuque (DBQ)
4. Washington (DCA)	4. Washington (DCA)
5. Houghton (CMX)	5. Houghton (CMX)
6. Muncie (MIE)	6. Muncie (MIE)
7. Palm Springs (PSP)	7. Palm Springs (PSP)
8. Keene (EEN)	8. Keene (EEN)
9. Bremerton (PWT)	9. Bremerton (PWT)
10. Auburn (AUO)	10. Columbus (CSG) and Montgomery (MGM)
11. Houston (HOU)	11. Houston (HOU)
12. Houma (HUM)	12. Houma (HUM)
13. Santa Fe (SAF)	13. Santa Fe (SAF)
14. San Luis Obispo (SBP)	14. Santa Maria (SMX), Paso Robles (PRB), and San Louis Obispo (SBP)

3. Data Processing. More than 52,500 hourly AWOS records and 52,000 hourly official observations were collected and archived for this study. To ensure the integrity of these two large data bases, an exhaustive effort was devoted to data editing. Data editing was initially performed by inspecting the data through a quality control program and error-checking routine designed to detect and flag any anomalous or spurious data points. The details of the AWOS data quality control program are provided in appendix A. These quality control and editing programs primarily identified garbled data, examined the AWOS processor status remarks, checked observations for normal range, and checked large excursions in the data from one hour to the next. Next, time

Station ID	Time GMT	Date	Sky and Ceiling	Visibility	Temp (°F)	Dew (°F)	Alt (in Hg)	Dir (°)	Speed (kt)	Gust (kt)	Den Alt	Precip	Status	Remarks
MIE	1500	1013	07S	50	46	42	977	300	9			02 E53	BB P	PRCP
MIE	1600	1013	07S	40	45	42	980	290	11			01 E59	P	PRCP
MIE	1700	1013	08S11S	55	45	42	981	290	8			01 E24	P	PRCP
MIE	1800	1013	10S	55	46	42	980	290	10					
MIE	1900	1013	27S	55	46	41	982	270	9					
MIE	2000	1013	CLR	55	48	38	983	290	9	14				
MIE	2100	1013	CLR	55	48	38	983	270	9	15				
MIE	2200	1013	CLR	55	49	35	984	260	10				H	
MIE	2300	1013	CLR	55	46	35	986	230	5				H	
MIE	0000	1014	CLR	55	44	34	987	200	6				H	
MIE	0100	1014	CLR	55	45	35	989	210	9				H	
MIE	0200	1014	CLR	55	42	37	992	260	5				H	
MIE	0300	1014	CLR	30	42	37	993	250	15	26		08 830	P	PRCP
MIE	0400	1014	CLR	55	40	36	993	230	8			00 E14	P	PRCP
MIE	0500	1014	CLR	55	39	34	994	240	10					

ID = Identification
GMT = Greenwich Mean Time
Temp = Temperature
Alt = Altitude
Hg = Mercury
Dir = Direction
kt = Knots
Den = Density
Precip = Precipitation

FIGURE 4. EXAMPLE OF HOURLY AWOS OBSERVATIONS

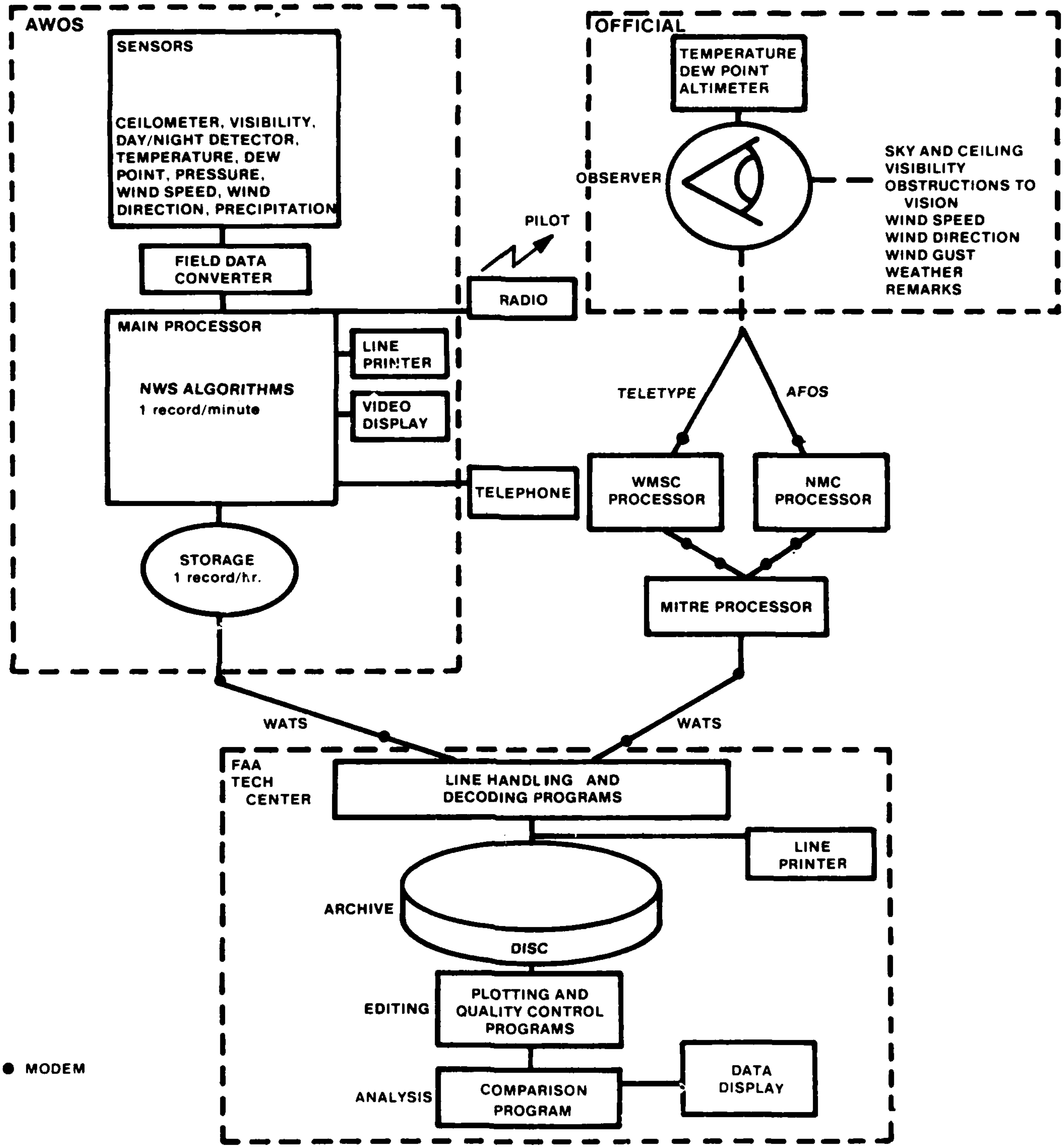

FIGURE 3. AWOS DATA ACQUISITION SYSTEM

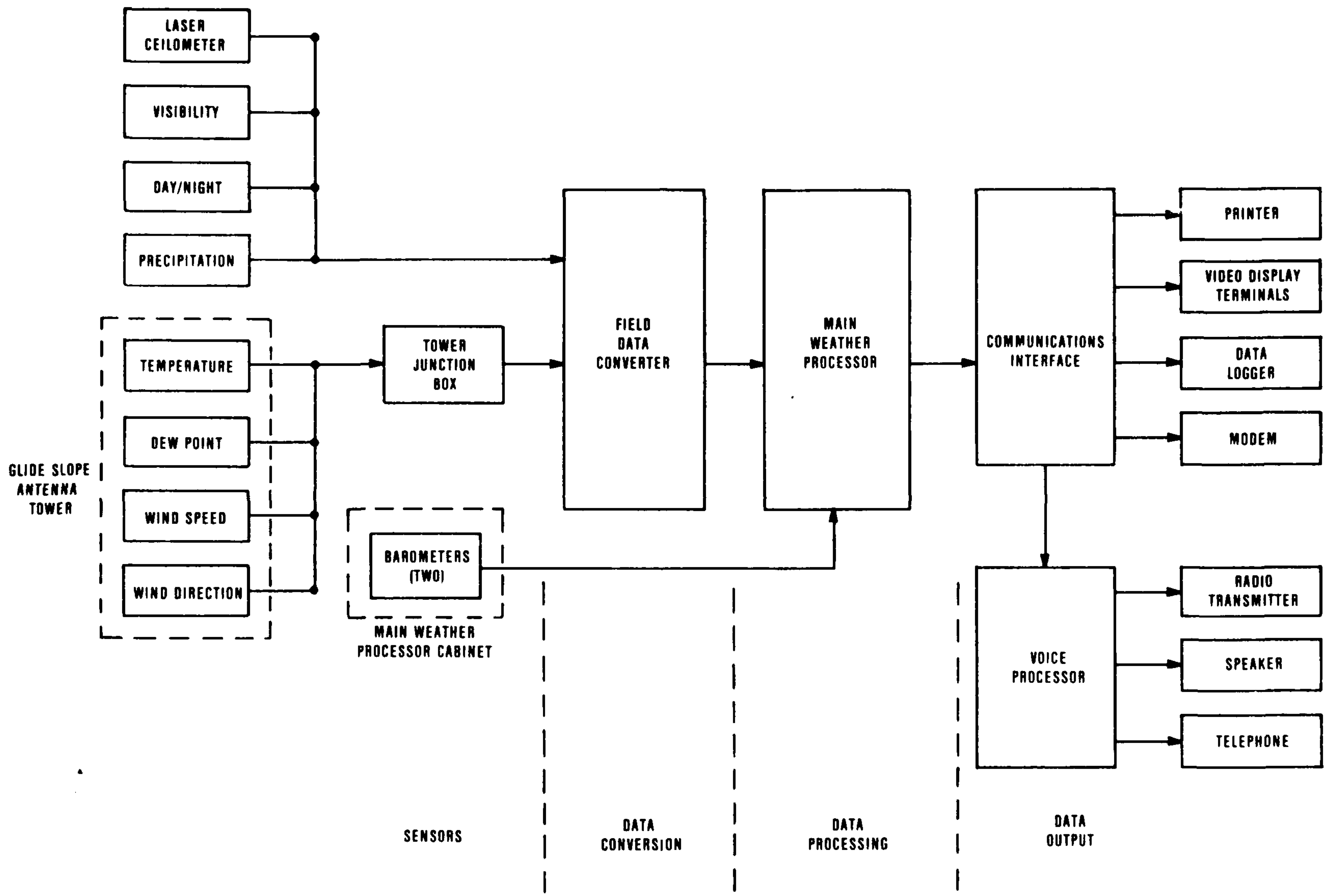

FIGURE 2. AWOS SYSTEM BLOCK DIAGRAM

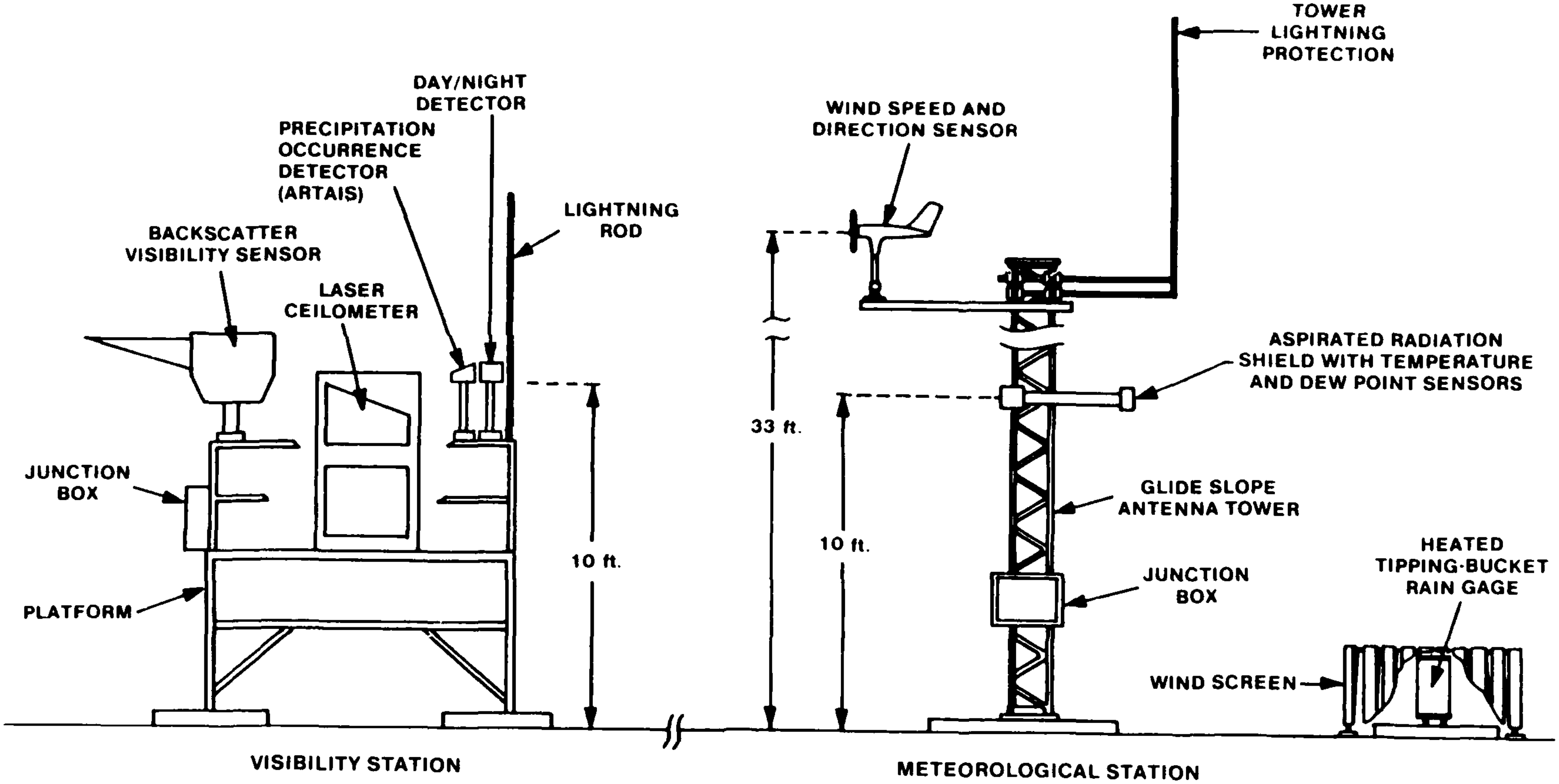

FIGURE 1. EXAMPLE OF AN AWOS FIELD SITE

REFERENCE DOCUMENTS.

During the course of the demonstration program the following documents were issued and are available from the Technical Center Library.

1. AWOS Demonstration Program Test Plan, DOT/FAA/CT-TN84/1, January 1984.

2. AWOS Quarterly Report, DOT/FAA/CT-TN83/60, December 1983.

3. AWOS Demonstration Program Bimonthly Report, DOT/FAA/CT-TN84/18-1, March 1984.

4. AWOS Demonstration Program Bimonthly Report, DOT/FAA/CT-TN84/18-2, May 1984.

SYSTEM DESCRIPTION.

1. AWOS. The AWOS System consists of commercially available meteorological sensors which measure nine atmospheric variables: cloud height, visibility, temperature, dew point, barometric pressure, wind speed, wind direction, precipitation occurrence, and precipitation amount. An illustration of a typical AWOS field site with its weather sensors is shown in figure 1. A generalized AWOS block diagram is shown in figure 2.

Sensor data were converted to digital form by a Data Collection Package (DCP) and sent to the AWOS Data Processing Unit (DPU) which reduced these data using algorithms provided by the National Weather Service (NWS). The AWOS DPU constructed and updated one record (or weather message) of observed and computed meteorological parameters once every minute. The DPU also synthesized this weather information into voice messages which were continuously transmitted to pilots over discrete very high frequency (VHF) or VHF omnidirectional range (VOR). These voice messages were also obtainable by pilots, flight planners, flight service personnel, and air traffic controllers through telephone dial-up access. AWOS information could also be monitored by direct link with a line printer or cathode ray tube (CRT) display. AWOS records processed at the beginning of each hour were automatically recorded on a nonvolatile storage medium such as disc or Read Only Memory (ROM). These storage devices were capable of holding up to 5 days of hourly reports and could be remotely accessed and reset. AWOS data used in this investigation were obtained directly from these storage devices.

2. Data Acquisition System. The method used for acquiring AWOS and official observations is illustrated in figure 3. Hourly weather reports recorded on the AWOS storage medium were automatically retrieved each weekday by the FAA Technical Center processor. Digital data were transmitted to this processor in American Standard Code for Information Interchange (ASCII) 320-byte physical record format via a band-6 Wide Area Telephone Service (WATS) line at a 1200-baud rate. Each physical record contains four 80-byte logical records, each of which corresponds to one hourly AWOS report. A baud rate of 300 was used for AWOS sites in Alabama and New Mexico. The retrieved data were simultaneously decoded and archived on hard disc by means of special-purpose line handling, decoding, and data base manager software programs. An example of archived AWOS hourly reports is shown in figure 4.

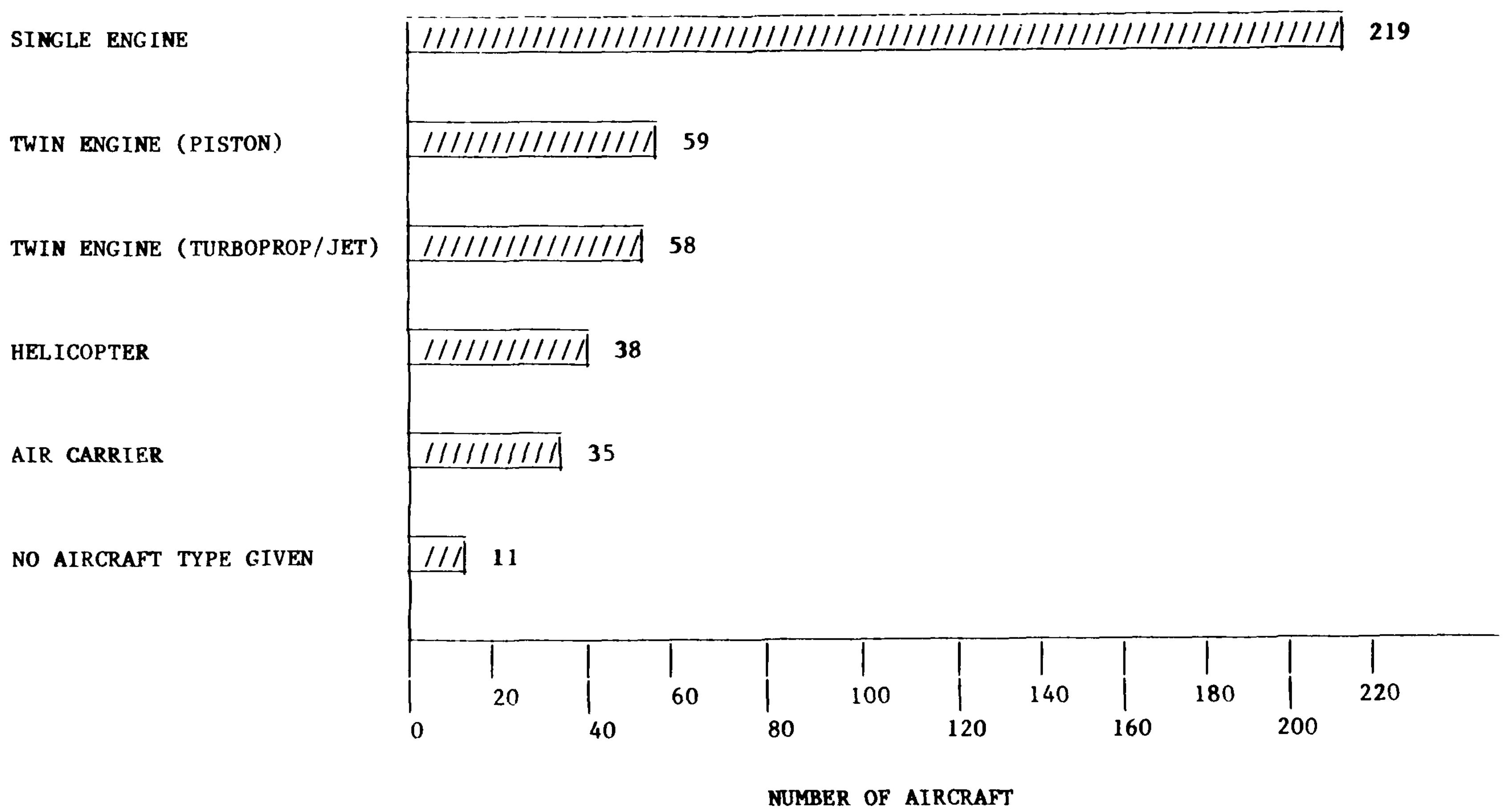

FIGURE 8. **AIRCRAFT TYPE USED BASED ON 420 QUESTIONNAIRES**

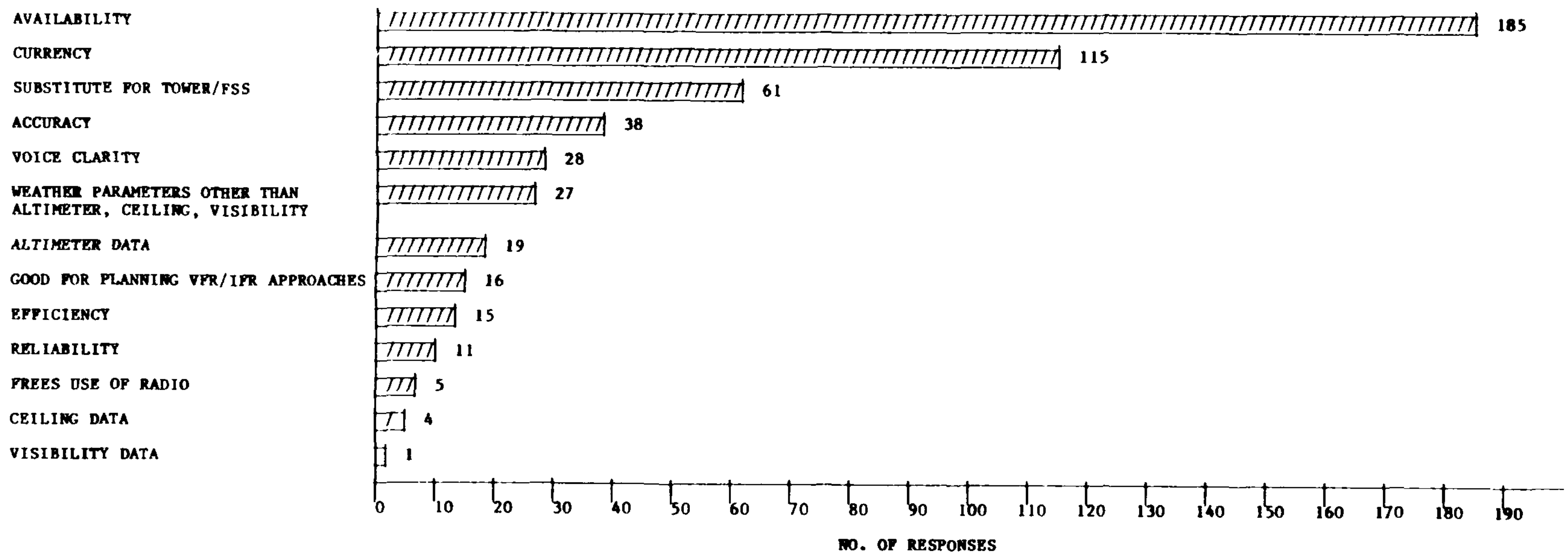

FIGURE 9. CATEGORIES OF FAVORABLE RESPONSES VS NUMBER OF RESPONSES

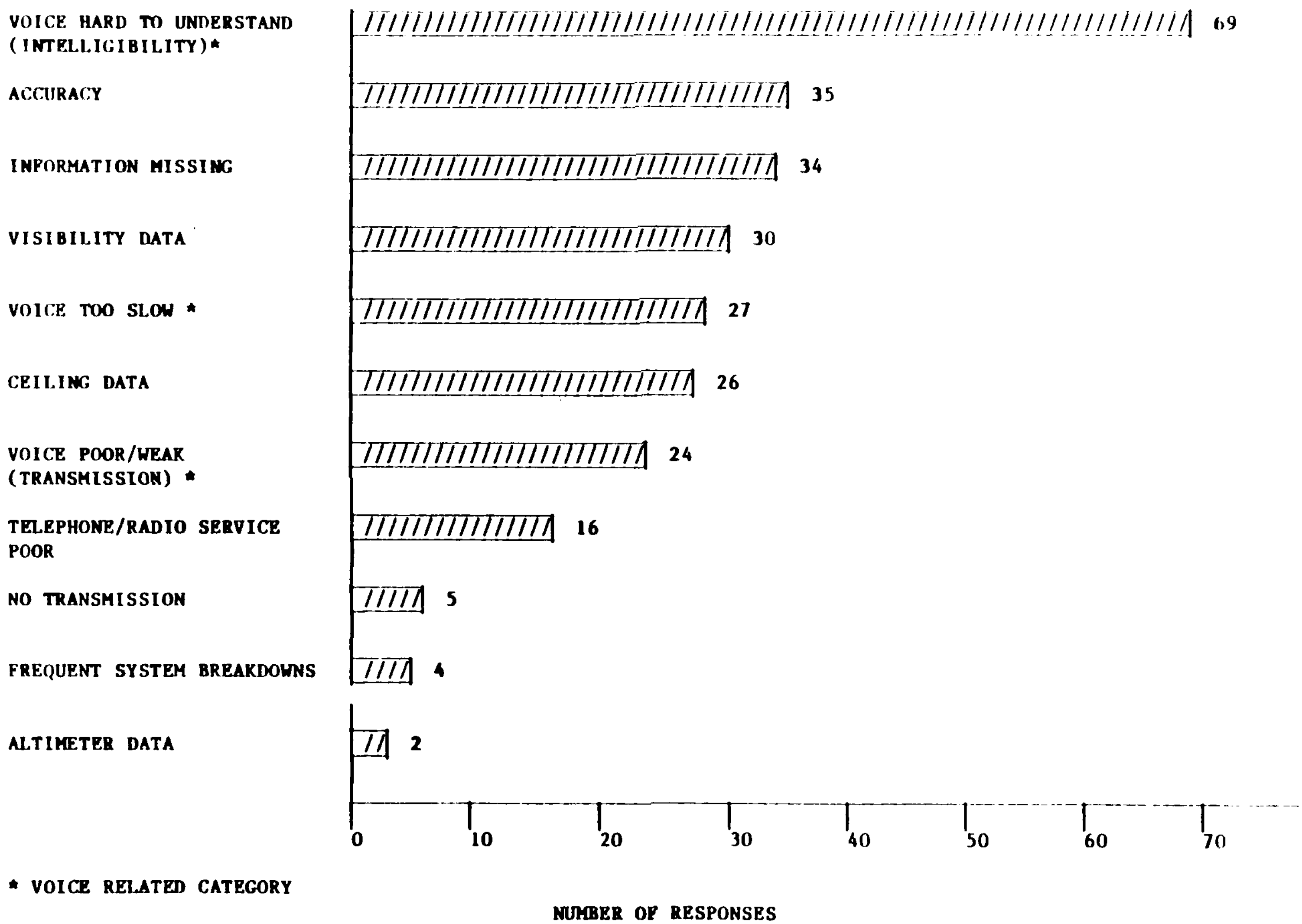

FIGURE 10. CATEGORIES OF UNFAVORABLE RESPONSES VS NUMBER OF RESPONSES

TABLE 4. UNFAVORABLE VOICE COMMENTS

Period	WeatherMeasure	Artais
September - December	17	15
January	14	3
February	8	3
March	30	7
April	12	2
May	5	3
June	0	1
Total	86	34

5. Descriptive Statistics. Response elements of the 420 pilot questionnaires were analyzed through various statistical methods. These questionnaire elements included:

System Rating

AWOS Ceiling (ft)

Pilot Ceiling (ft)

AWOS Visibility (mi)

Pilot Visibility (mi)

Average Pilot Flying Hours/Yr

The differences between AWOS ceiling and pilot ceiling responses and AWOS visibility and pilot visibility responses were similarly analyzed. Computer programs of the 1983 BMPD Statistical Software Package were employed in performing the statistical calculations of the analyses. Descriptive statistics for the variable in each instance included the frequency of occurrence, sample mean, standard deviation, standard error of the mean, coefficient of variation, and minimum and maximum values. The computer-generated results for these statistics are presented in table 5. A referral to the 1983 BMPD statistical software package can be found in Technical Note DOT/FAA/CT-TN84/18-1.

6. System Rating. Overall rating of AWOS was established as the primary measure of importance in the pilot questionnaire survey. Pilots were requested to respond by giving a numerical rating from 1 (poor) to 5 (excellent). The mean of the pilot ratings of the system was 3.64, as indicated in table 5; the standard error of this mean value (i.e., sampling error) is 0.062.

TABLE 5. DESCRIPTIVE STATISTICS

	Variables	Frequency	Mean	Standard Deviation	Standard Error of Mean	Coefficient of Variation	Minimum Value	Maximum Value
1.	Rating	420	3.64	1.28	0.062	0.351	1.00	5.00
2.	AWOS Ceiling (ft)	233	3221.03	1904.70	124.781	0.591	100.00	5000.00
3.	Pilot Ceiling (ft)	233	3373.09	1850.51	121.231	0.549	150.00	5000.00
4.	AWOS Visibility (mi)	239	4.67	1.42	0.092	0.304	0.25	5.50
5.	Pilot Visibility (mi)	240	4.89	1.27	0.082	0.260	0.38	5.50
6.	Average Pilot Hours	412	386.88	322.56	15.891	0.834	10.00	1400.00
7.	Sky Conditions Difference (ft)	233	-152.06	1298.99	85.099	-8.543	-4900.00	4800.00
8.	Visibility Difference (mi)	239	-0.22	1.14	0.074	-5.280	-5.00	4.50

7. Difference Between AWOS and Pilot Reported Ceiling. The AWOS reported ceiling had an arithmetic mean of 3,221 feet with a standard deviation of 1,904 feet. The standard deviation is quite large due to the number of observations at the extremes, especially at the upper extreme. The minimum report was 100 feet; the maximum report was 5,000 feet. This maximum report of 5,000 feet occurred in 106 (45.5 percent) cases out of the 233 pilot questionnaires that included information about the AWOS reported ceiling.

The pilot report ceiling had very similar statistics. The arithmetic mean was 3,373 feet, indicating an average bias between AWOS reported and pilot reported ceiling of 152 feet. The variable ceiling difference is obtained by subtracting the pilot reported lowest cloud level from the AWOS reported lowest cloud level. The standard deviation of 1,850 feet was fairly close to that of the AWOS reported ceiling. A paired Student t test was performed and the results indicate no statistically significant difference between the arithmetic mean of the AWOS and pilot report ceiling.

8. Difference Between AWOS and Pilot Reported Visibility. AWOS visibility is reported discretely only up to a range of 5 miles. Consequently, as a ground rule for the analysis of visibility, pilot reported visibilities of 6 miles or larger were treated as a maximum report of greater than 5 miles. The difference between the AWOS reported and pilot reported visibility under these maximum situations was zero.

The AWOS reported visibility had an arithmetic mean of 4.67 miles with a standard deviation of 1.42 miles. The pilot reported visibility had similar statistical values with a mean of 4.89 miles and a standard deviation of 1.27 miles. The mean of the visibility difference was -0.22 miles with a standard error of 0.074 miles.

A two-factor analysis test of variance was performed to determine which of the factors, visibility, ceiling, or both, significantly affected the system rating. Each factor was divided into two levels. For ceiling, differences were grouped as 200 feet or less, and more than 200 feet. For visibility, differences were established as less than or equal to 0.5 miles and greater than 0.5 miles. The groupings selected represent the tolerance levels for the variables identified in the AWOS Demonstration Program Test Plan.

The raw cell means of the system ratings for this grouping are depicted in table 6. The table shows that the system rating was 1.88 when AWOS was reporting ceilings which differed by greater than 200 feet from the pilots observation in combination with an AWOS report of visibility which differed by greater than 1/2 mile from the pilots observation.

From an overall standpoint pilot ratings, as expected, are lowest when visibility differences exceed 0.5 miles and, at the same time, ceiling differences exceed a 200-foot threshold. Pilot ratings are relatively high when either visibility or ceiling (or both) are less than the threshold values shown in table 6.

TABLE 6. SYSTEM RATING ACCORDING TO VISIBILITY AND CEILING DIFFERENCES

Visibility Differences	Ceiling Differences	
	≤200 ft	>200 ft
≤0.5 miles	3.86	3.09
>0.5 miles	3.39	1.88

9. Scatter Plot of Sky Condition Difference Versus Visibility Condition Differences. The scatter plot of the sky condition differences and associated visibility differences are shown in figure 11. The plot shows results are centered at the origin (0,0) with 118 cases out of 212 (55.7 percent) reporting no differences in sky and visibility.

10. Analysis of Rating Versus Location. An analysis was performed to detect any dependence of overall system rating on system location. There were significant differences in system ratings at the 14 different locations, as shown in table 7. Several other multiple comparison tests confirmed this finding. Also, pilot responses were reviewed to see if either of the two AWOS Systems had any effect on system rating. As shown in table 8, system type had no significant effect on pilot rating.

TABLE 7. LOCATION EFFECTS ON RATING

	Location	Count N	Rating Mean	Standard Deviation
	WeatherMeasure			
1.	AUO	20	4.45	0.6863
2.	HOU	28	2.75	1.5546
3.	EEN	55	3.45	1.3953
4.	MIE	32	3.47	1.2439
5.	PSP	24	3.83	0.9168
6.	SBP	52	3.91	0.9788
7.	GAL	1	2.00	0.0000
	Artais			
8.	DCA	29	3.74	1.2861
9.	DBQ	50	3.90	1.1429
10.	HUM	36	4.19	0.8559
11.	CMX	27	2.59	1.3085
12.	PWT	29	4.00	1.0690
13.	SAF	27	3.04	1.4273
14.	VDZ	6	4.33	0.8165

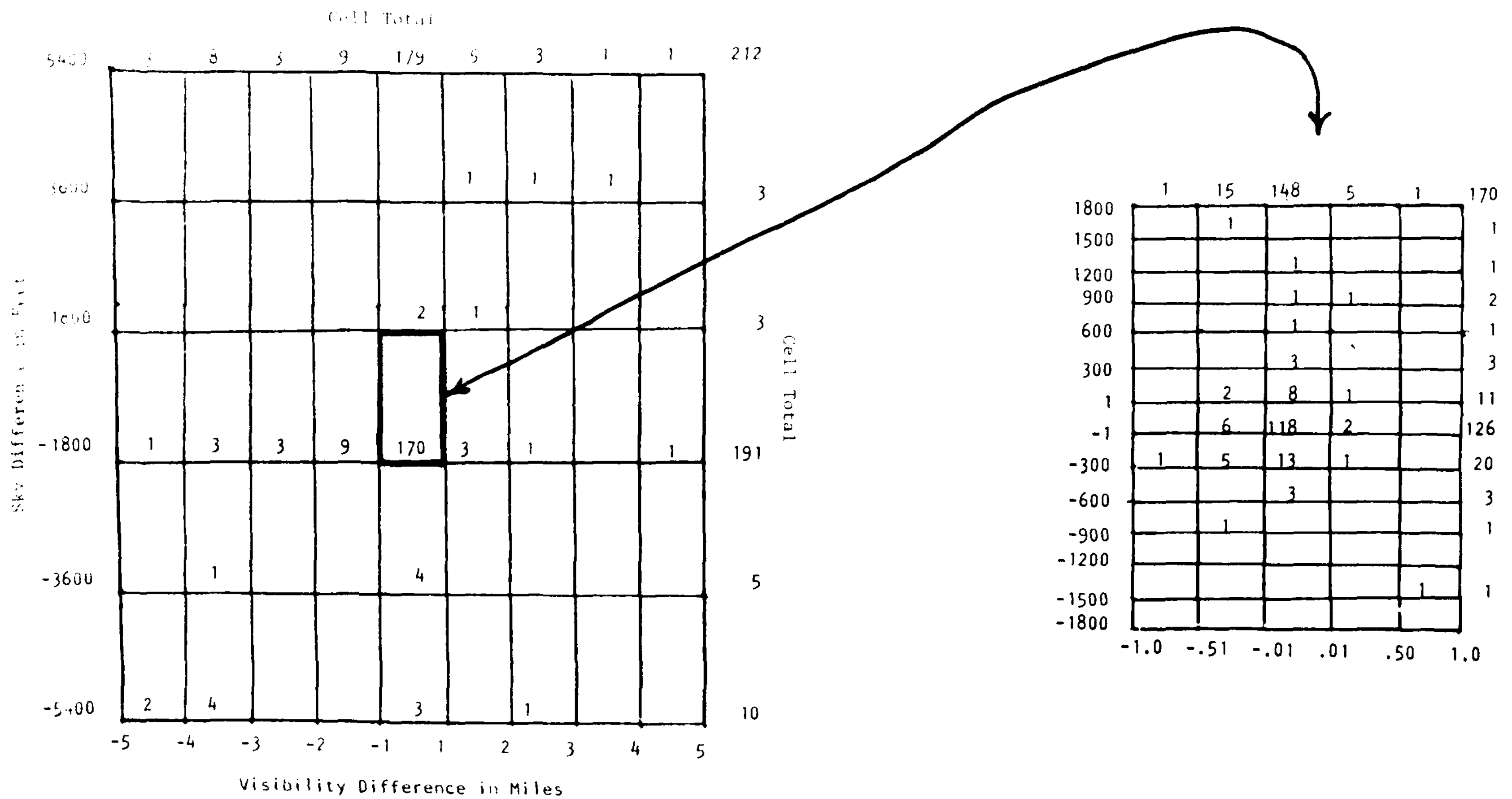

FIGURE 11. SKY CONDITION DIFFERENCE VS VISIBILITY CONDITION DIFFERENCE

TABLE 8. RATING ACCORDING TO SYSTEM TYPE

System	Count (N)	Mean Rating
WeatherMeasure	212	3.61
Artais	204	3.67

11. Method of Access. The methods of access to the AWOS recorded messages were: VOR, discrete VHF (dVHF), FSS Specialist, ATC, and telephone. It was observed in the tabulation of pilot responses that some pilots gave multiple entries to this question of method of access. Hence, certain ground rules were established in order to focus the multiple entry responses to a single primary method of access. These ground rules were: radio access had priority over telephone and VOR had priority over dVHF. For example: in multiple responses of VOR and telephone, only VOR was recorded; where VOR, dVHF, and telephone were all checked off, only VOR was recorded. Finally, in the example where dVHF special and telephone were both checked off, only dVHF was recorded.

A comparison was made to test the effect that method of system access had on the AWOS System rating. Of the 420 pilot questionnaires, 406 were evaluated as system access either by telephone, dVHF, or through the VOR frequency. Table 9 is a table of results.

These data show that system rating was highest when the pilot accessed AWOS on a dVHF. This table led to the observation that a Student t test comparison should be made on radio versus telephone access (radio including both dVHF and VOR). The results compared against system rating is presented in table 10. The t test showed a slightly higher mean rating for radio (3.70) than telephone (3.38).

TABLE 9. ACCESS EFFECT ON RATING

Method of Access	System Rating	Count (N)	Standard Deviation
VOR	3.44	179	1.34
dVHF	4.01	144	1.03
Telephone	3.38	83	1.40

TABLE 10. TELEPHONE VERSUS RADIO ACCESS ON RATING

Method of Access	System Rating	Count (N)	Standard Deviation
Telephone	3.38	83	1.40
Radio	3.70	323	1.25

12. Voice Effect on Rating. Another analysis performed compared the effect of unfavorable voice comments to pilot rating. The unfavorable voice comments were categorized into three classes: voice too slow, voice hard to understand, and poor transmission. The results of this variance test of voice effect on rating is given in table 11. Results show system ratings were substantially lower when the pilot had difficulty with message intelligibility such as "Voice Hard to Understand" and "Poor Transmission."

TABLE 11. VOICE EFFECT ON RATING

Voice Effect	System Rating	Count (N)	Standard Deviation
Too slow	3.85	27	0.82
Hard to understand	3.07	69	1.25
Poor transmission	3.00	24	1.44

13. Correlation of System Rating With Other Variables. A system rating comparison test was run comparing the 64 Jeppesen AWOS questionnaire forms against the 356 OMB approved questionnaires. No significant differences were found between the two groups.

14. Instrument Flight Rules Versus Visual Flight Rules Effect. System rating according to whether the pilot was operating under Instrument Flight Rules (IFR) or Visual Flight Rules (VFR) was analyzed. Tabulation of the responses indicated that 167 pilots operated under IFR conditions and 202 under VFR conditions. Of those pilots who responded to this questionnaire, 45.3 percent flew IFR and 54.7 percent flew VFR. Paired Student t tests were conducted to test the IFR/VFR effect. The IFR mean system rating was 3.77; the mean system rating for VFR was 3.53. Consequently, whether or not the pilot was IFR or VFR had no significant effect on his rating of system performance.

MTBF AND MTTR ANALYSES.

1. General. Computations of MTBF and MTTR were performed by system and by each sensor for each manufacturer (WeatherMeasure and Artais) for each of the 14 AWOS sites. These computations were based on the review and assessment of data contained in Airways Facilities Performance, Failure, and Repair Logs periodically forwarded to the FAA Technical Center from the various sites. In scope, these data covered the 10-month period from September 1983 through June 1984.

The standard procedures followed in assessing the logs involved determinations as to completeness and applicability of the data. When additional or clarifying information was needed, telephone discussions were held with the technicians at those sites of concern. Further, annotations were made adjacent to the log entries to identify type of failure category, i.e., system failure (as defined in the AWOS test plan) or sensor failure. Failures that were not applicable (e.g., data retrieval) were annotated as "OMITS."

2. <u>MTBF Analysis Methodologies</u>. Two distinct methodologies were necessary for calculating AWOS System and sensor MTBF's. One method was used for calculating the estimated MTBF, while the other involved calculating the confidence limits of the true MTBF. Calculation of estimated MTBF values was employed when two or more failures occurred. When one failure or no failure occurred over the duration of the AWOS demonstration program, the confidence limits of the true MTBF were calculated.

The basic reason for implementing two different calculating methodologies stems from the inherent meaning of MTBF, i.e., mean-time-between-failures. Consequently, at least two failures must occur before normal calculations of the estimated MTBF can take on practical meaning.

3. <u>MTBF Calculations (Two or More Failures)</u>. Estimates of the MTBF for two or more failures were calculated for the system and each of the seven sensors at each site by means of the fundamental expression:

$$MTBF = \frac{TOT}{n} , \tag{1}$$

where TOT represents the total operating time and n the number of failures (two or more) during the period.

In calculations of system MTBF for each site,

TOT = Total period time - Σ(total time to restore + preventative maintenance time)

However, in calculations of sensor MTBF (for each sensor) for each site, the expression was modified as follows:

TOT = Total period time - Σ(total time to restore + preventative maintenance time) - Σ(down time due to a system failure)

For sensors, there are two contributing factors:

a. Cases in which the system was operational but the sensor was down.

b. Cases in which the system itself was down and, consequently, the sensors were not operational.

Further, in nearly all instances, preventative maintenance time did not occur. This reduced the expression for TOT for calculating purposes of system MTBF to:

TOT = Total period time − Σ(total time to restore);

and for sensor MTBF to:

TOT = Total period time − Σ[(total time to restore) + (down time due to a system failure)].

As a basic ground rule for the analysis, total period time, on a month by month basis, was established as 720 hours. As a result, overall total cumulative period time for the 10-month demonstration program was 7,200 hours.

4. Confidence Limits of the True MTBF (One or No Failures). If $T = \Sigma t_i$ hours of operating time are accumulated and r failures are observed in such a test, which can be of the replacement or nonreplacement type, the two-sided confidence limits for a 100 (1−α) percent confidence level are given by:

$$\frac{2T}{\chi^2_{\alpha/2;2r+2}} \leq m \leq \frac{2T}{\chi^2_{1-\alpha/2;2r}} \tag{2}$$

and the one-sided confidence limit at the same level is given by:

$$m \geq \frac{2T}{\chi^2_{\alpha;\,2r+2}} \tag{3}$$

Further, even if no failure occurs during the test (r = 0), a definite lower confidence limit can be calculated (Bazosky, Igor, Reliability Theory and Practice, Prentice-Hall, 1961, pg. 238) i.e.,

$$C_L = \frac{2T}{\chi^2_{\alpha;2}} \tag{4}$$

In the above statistically related expressions, "m" represents the true MTBF, "T" the total operating time, "t_i" the elements of operating time, "r" the number of failures, "C_L" the lower confidence limit, "α" the level of significance, and "χ^2" the Chi-square random variable.

The general inequality expression for determining two-sided confidence limits for the true MTBF (equation 2) was applied to those cases in which only one system or sensor failure occurred during the 10-month AWOS demonstration program. The confidence level selected was 80 percent; hence $\alpha = 0.20$. Substituting and simplifying, the specific expression resulted as:

$$\frac{2T}{\chi^2_{.10;4}} \leq m \leq \frac{2T}{\chi^2_{.90;2}}$$

Values for the two denominators of the expression were determined from statistical tables for percentiles of the Chi-square distribution. This enabled the following inequality expression to be developed for actual computational usage:

$$\frac{2T}{7.78} \leq m \leq \frac{2T}{0.2107}$$

Consequently, to perform the actual computations, all that needs to be known is the respective total operating time (T) of each system or sensor experiencing one failure. With this information, the two-sided confidence limits of the true MTBF can be determined for each situation.

In those instances in which a system or sensor experienced no failure (r = 0) during the 10-month time frame, the lower confidence level was calculated using equation 4 cited earlier. The confidence level selected was 90 percent; hence $\alpha = .10$. The value for $\chi^2_{.10;2}$ from statistical tables was found to be 4.61. Substituting this value, yields the following basic expression used for computational purposes:

$$C_L = \frac{2T}{4.61} \tag{7}$$

5. Failure Distribution Results. Table 12 provides, in matrix-type format, data concerning the distribution in number of failure occurrences during the 10-month AWOS demonstration program for each manufacturer (WeatherMeasure and Artais). The horizontal matrix heading, in each instance, are the three-character identifiers for the seven associated AWOS sites. Listed vertically in the first column are the system and sensor names. Entries in the body of each matrix reflect the distribution in number of failure occurrences. To determine the actual number of failure occurrences for any situation, read across the row (system or specific sensor) and down the site column. The number of failures appears at the intersection of the row and column.

An analysis of these failure distributions revealed, in general, that WeatherMeasure and Artais had almost the same total instances of two or more failures (13 versus 14 in count) and one or no failures (43 versus 42 in count) respectively. This information was particularly useful in terms of bringing into focus the type of MTBF calculating methodology to be employed.

Contrasting differences, however, were noted within these distributions. Artais had a substantially greater number of two or more failure cases than WeatherMeasure (208 versus 42, respectively). The primary contributor to the high Artais count was the large number of system failures (184), most of which

TABLE 12. TOTAL NUMBER OF FAILURES

Weather Measure	AUO	HOU	EEN	MIE	PSP	SBP	GAL	Total
System	5	1	3	1	2	3	1	16
Ceiling	0	2	2	2**	1	0	1	8
Visibility	0	0	12	0	1	3	0	16
Wind	0	1	0	0	0	0	0	1
Temperature	0	0	0	2	0	0	0	2
Dew Point	0	0	0	1	0	0	0	1
Precipitation	0	1	2	2	0	0	0	5
Altimeter	0	1	2	0	0	0	0	3
Total	5	6	21	8	4	6	2	52

Artais	DCA	DBQ	HUM	CMX	PWT	SAF	VDZ	Total
System	18	14	54	48	39	5	6	184
Ceiling	1	6	1*	1	1	0	1	11
Visibility	0	1	6	0	1	0	0	8
Wind	0	1	0	1	0	0	2	4
Temperature	0	0	0	0	0	1	0	1
Dew Point	1*	2	4	1	1	0	1	10
Precipitation	1*	0	2	2**	0	0	0	5
Altimeter	1	1	0	1	0	0	0	3
Total	22	25	67	54	42	6	10	226

Note:
* Failure not resolved
** Last failure not resolved

occurred at HUM, CMX and PWT. For WeatherMeasure, the highest count of two or more failures was for the visibility sensor failure at EEN (12). Insofar as the distribution of occurrences of one or no failures, WeatherMeasure had 10 instances of one failure and 33 instances of no failures; whereas, Artais had 18 instances of one failure and 24 instances of no failure.

The overall total counts of failure occurrences during the 10-month time frame were 52 for WeatherMeasure and 226 for Artais. At the termination of the AWOS Demonstration Program on June 30, 1984 (i.e., last data collected on June 30), there were five instances in which failure situations had not been resolved, one at a WeatherMeasure site and four at Artais sites. These related to a second ceiling sensor failure at Muncie, initial occurrences of dew point and precipitation sensor failures at Washington, D.C., a ceiling sensor failure at Houma, and a second precipitation sensor failure occurring at Houghton.

6. Estimated MTBF and Confidence Limit Results. Appendix B affords 14 sets of tables, one set for each of the seven WeatherMeasure sites and seven Artais sites. Each set consists of eight tables which provide, in sequenced order, a record of the system data and corresponding sensor data computational results for total operating time and number of failures. The ordering of the sensor data is as follows: ceiling, visibility, wind, temperature, dew point, precipitation, and altimeter. The tabular data for WeatherMeasure are shown in tables B-1 through B-8, while Artais data appear in tables B-9 through B-16. Results are given cumulatively for the time from September 1983 through June 1984.

It is to be noted that cumulative operating time is given in all instances even when there are no failures. Inspection of the sensor data reveal differences in operating time since down time due to a system failure plays a role. The calculated results of estimated MTBF for each time period are shown in the last column of each table, when applicable. This practice adheres to the methodology discussed earlier for calculating estimated MTBF values only when a system or sensor incurred two or more failures. Appearing in the last row of each system and sensor table are the aggregate cumulative data results for the 10-month AWOS Demonstration Program.

Tables 13 and 14 provide overall MTBF computational results for WeatherMeasure and Artais, respectively, for the 10-month AWOS Demonstration Program. The format of these tables is analogous to table 12. Entries consist of the numerical values for: (1) the lower confidence limits of the true MTBF at the 80 percent confidence level for cases of no failure occurrences; (2) the two-sided (lower and upper) confidence limits of the true MTBF at the 80 percent confidence level for cases of one failure occurrence; and (3) the estimated MTBF's corresponding to two or more failure situations.

The designators "L" and "U", appearing to the left of certain entries, represent that these numerical entries are the lower and upper confidence levels of the true MTBF. In cases where a numerical value appears after an "L" designator and a dash after the "U" designator, the numeric represents the lower confidence limit of the true MTBF, while the dash denotes there is no upper bound insofar as a confidence limit (i.e., these apply to no failure situations). Finally, when a numerical value appears without any designators, this represents the estimated value of MTBF (i.e., the case for two or more failure occurrences).

The intervals in table 20 were selected based on the accuracy and quantizing increment of the particular atmospheric parameter. As an example, if the computed confidence interval for dew point is $\mu = \bar{d} \pm 1.2$ °F, then the sample bias is accepted as being statistically significant (with actually greater than 95 percent confidence) since the width of the confidence interval is less than the prescribed limit of ± 2 °F in table 20.

The accuracy of the reliability index RI estimate may also be determined by establishing a confidence interval for its population counterpart p. Since the statistic RI is approximately normally distributed, the 95 percent confidence interval for p is

$$p = RI \pm z_{.975} \left[\frac{RI(1-RI)}{N} \right]^{\frac{1}{2}} \tag{21}$$

In this study, computed values of RI were accepted as being statistically significant at the 95 percent confidence level when the confidence interval in equation 21 was within RI ± 5 percent.

Inspection of the foregoing formulas for significance testing on the sample correlation coefficient, bias value, standard deviation, and reliability index show that the accuracy of a computed statistic increases as the sample size N increases, or the level of confidence is relaxed. Consequently, rejection of a computed statistic, because of statistical insignificance at a certain confidence level, is a result of an insufficient sample size.

A common method of determining the required sample size to obtain statistically significant results is based on the confidence interval for the true bias. The relationship in equation 19 can be alternately used to estimate the sample size required to produce a sample bias estimate of a desired accuracy; i.e., how large must the sample size N be in order to be at least 95 percent assured the true bias is $\mu = \bar{d} \pm E$. After rearranging equation 19, the required sample size $N_{\bar{d}}$ can be stated as

$$N_{\bar{d}} = \left[\frac{s \; t_{N-1;.975}}{E} \right]^2 \tag{22}$$

where E is the tolerance given in table 20. Analogously, a required sample size for a reliability index estimate of desired accuracy can be obtained by rearranging the confidence interval formula given in equation 21.

Data Display.

a. General. A set of general-purpose plotting routines were developed for graphical display of the comparison analysis results. These routines were used to construct for each meteorological parameter and particular case study: time series plots of residual differences, scattergrams of AWOS on observed values, and relative and cumulative frequency histograms of residuals. As a sample, a complete set of plots for AWOS sites at Washington, D.C., and Houston, is given in figures D-1 through D-30 of appendix D. These figures display time series plots, scattergrams, and histograms for each of the eight meteorological variables.

A statistically significant correlation occurs when the value of $w\sqrt{N-3}$ falls outside the interval given by equation 17. In other words, when the absolute value of $w\sqrt{N-3}$ is greater than 1.96, we reject the hypothesis $\rho_{xy}=0$ and say that we are 95 percent confident that a significant correlation exists between x and y.

In order to determine the accuracy of the sample bias and standard deviation, it is desirable to examine these estimates in light of confidence intervals constructed for their population counterparts. Theoretical sampling distributions for the sample bias $\bar{d}$ and standard deviation s, when N observations are made from a population with unknown mean μ and standard deviation σ, are Student-t and chi-square distributions, respectively. Then the 95 percent confidence intervals are

$$\mu = \bar{d} \pm \frac{s t_{N-1;.975}}{\sqrt{N}} \tag{19}$$

and

$$s\left[\frac{(N-1)}{\chi^2_{N-1;.975}}\right]^{\frac{1}{2}} \leq \sigma \leq s\left[\frac{(N-1)}{\chi^2_{N-1;.025}}\right]^{\frac{1}{2}} \tag{20}$$

where t and χ^2 are the Student-t and chi-square random variables with N-1 degrees of freedom. By virtue of the symmetry of these sampling distributions, the true bias is centered exactly within its confidence interval, while the position of σ within its confidence interval is typically skewed towards one bound or the other. One constraint on equation 20 is that the sample is drawn from a normally distributed population. This assumption is reasonable in our case since the distribution of residual differences is approximately normal.

In this study, values of the bias and standard deviation were accepted as being statistically significant only when their respective 95 percent confidence intervals were entirely contained within a prescribed tolerance interval. That is, the confidence interval must be within the acceptance interval $\bar{d} \pm E$ or $s \pm E$. The acceptance limit E for each meteorological parameter is in table 20.

TABLE 20. CONFIDENCE INTERVAL TOLERANCES FOR MEAN AND STANDARD DEVIATION

Parameter	E
Cloud Height (ft)	100
Visibility (mi)	0.25
Temperature (°F)	1.0
Dew Point (°F)	2.0
Altimeter (in Hg)	0.01
Wind Direction (deg)	10
Wind Speed (kt)	2
Wind Gust (kt)	2

The values of e in table 19 are based primarily on the sensor functional rms error requirements stated in the AWOS Test Plan. A reliability index for precipitation is defined as the percentage of times AWOS and the official observer jointly reported yes or no for precipitation occurrence.

TABLE 19. ACCEPTANCE LIMITS FOR RELIABILITY INDEX COMPUTATION

Parameter	e
Cloud Height (ft)	200 for official $\leq$ 1500
	400 for official $>$ 1500
Visibility (mi)	0.5 for official $\leq$ 2
	1.0 for official $>$ 2
Temperature (°F)	3
Dew Point (°F)	4
Altimeter (in Hg)	0.05
Wind Direction (deg)	35
Wind Speed (kt)	5
Wind Gust (kt)	5

d. Significance Tests. After a sample statistic is computed, it is customary to test how accurate the sample value estimates the true population value. This is carried out by either statistical hypothesis testing or confidence interval construction. In this section, the procedures used to evaluate the accuracy of the sample linear correlation coefficient, mean value, standard deviation, and reliability index are outlined. These parameters were tested since they are the primary statistics used in judging AWOS performance. As a rule, a 95 percent level of confidence was assumed throughout.

The accuracy of the correlation coefficient estimate r_{xy} in estimating the true correlation coefficient ρ_{xy} is often evaluated by testing the hypothesis $\rho_{xy}=0$. Rejection of this hypothesis as a result of the significance test implies that, through the correlation coefficient estimate r_{xy}, a significant relationship indeed exists between the random variables x and y. An acceptance interval for the hypothesis $\rho_{xy}=0$ is given by

$$-z_{.975} \leq w\sqrt{N-3} \leq z_{.975} \qquad (17)$$

where the sample size N is the number of paired measurements and z is the standardized normal random variable (see Technical Note DOT/FAA/CT-TN83/60). In this relationship, w is a transformation function of r_{xy} given by

$$w = \tfrac{1}{2}\log_e\left[\frac{1 + r_{xy}}{1 - r_{xy}}\right] . \qquad (18)$$

This function facilitates the use of the acceptance interval in equation 17 since w has the convenient property of being approximately normally distributed.

The sample mean difference is simply the arithmetic mean of differences over the time series and was computed for each parameter according to the sample mean value relationship

$$\bar{d} = \frac{1}{N} \Sigma d_i \tag{12}$$

where the sample size N is the number of independent differences and d_i is the instantaneous difference value given by equation 11. The sample mean difference $\bar{d}$ is also called a mean bias value which is representative of the static or systematic component of the noise. For example, a large bias value usually indicates that the sensor being compared may be out of calibration.

The dynamic or fluctuating component of the noise about the bias is described by the sample standard deviation. This parameter is the most common statistic used for estimating variation or dispersion. Computation of the sample standard deviation, defined by

$$s = \left[\frac{1}{N-1} \Sigma(d_i - \bar{d})^2 \right]^{\frac{1}{2}} \tag{13}$$

was carried out by means of a more computationally efficient formula:

$$s = \left[\frac{N \Sigma d_i^2 - (\Sigma d_i)^2}{N(N-1)} \right]^{\frac{1}{2}} \tag{14}$$

The rms value is a suitable statistic since it contributes a combined measure of both the static and fluctuating components of the noise about a reference level of zero error. Subsequently, estimation of the rms value of the noise (rms error) is provided in terms of the sample mean value and standard deviation through the relation

$$rms = \left[\frac{N-1}{N} (s)^2 + \bar{d}^2 \right]^{\frac{1}{2}} \tag{15}$$

In this equation, the first term in brackets is a form of the population variance. A desirable characteristic of the mean difference, standard deviation, and rms value is that the physical units of these statistics are the same as the parameter difference d_i.

The reliability index is an empirical parameter set forth in the AWOS Test Plan. It is defined as the proportion of the total sample of differences which falls within specified tolerance bounds. In equation form, the reliability index is given by

$$RI = \frac{1}{N} \Sigma X_i \qquad \begin{aligned} X_i &= 1 \text{ for } |d_i| \leq e \\ X_i &= 0 \quad |d_i| > e \end{aligned} \tag{16}$$

where the value of e for each meteorological parameter is provided in table 19.

Once the degree of agreement and type of interdependence between AWOS measurements and official observations are discerned through the sample linear correlation coefficient, it is customary to employ a regression analysis to determine the underlying relationship between the two data sets. A technique commonly used in finding a linear relationship is a least-squares procedure which provides the best-fit straight line (linear regression line) through the paired measurements. The equation of the linear regression line for N paired measurements of y on x is y = ax + b where the coefficients

$$a = \frac{N(\Sigma x_i y_i) - (\Sigma x_i)(\Sigma y_i)}{N\Sigma x_i{}^2 - (\Sigma x_i)^2} , \tag{9}$$

and

$$b = \frac{\Sigma y_i - a\Sigma x_i}{N} , \tag{10}$$

are the slope and y-intercept of the linear regression line, respectively. In this investigation, a favorable linear relationship between x and y is displayed when the slope "a" is approximately equal to one and the y-intercept "b" is close to zero.

c. <u>Time Series Analysis</u>. Another useful way of comparing the AWOS data with the official data is to describe the temporal variation of AWOS deviations from the corresponding official observations. This was carried out by first constructing time series of instantaneous differences (or residuals) according to the relation

$$d(t) = x_A(t) - x_O(t) , \tag{11}$$

where, at any time "t", the difference "d" is defined as the AWOS measurement x_A minus the corresponding official observation x_O.

The difference "d" is not an absolute measurement of the error in AWOS since the reference value x_O is not necessarily a precise or accurate standard. For this investigation, however, the official observations were assumed to be reliable and, therefore, the time series of differences is essentially representative of the undesired error (or noise) in AWOS. The theoretical probability distribution which typically describes these random errors is the well-known normal or Gaussian distribution.

The objective of the time series analysis is to express the overall amount and distribution of this noise in terms of suitable statistical parameters. Four statistical estimators selected for describing the error characteristics are the mean difference, standard deviation, rms value, and reliability index.

AWOS VERSUS OFFICIAL COMPARISON ANALYSES.

1. Data Reduction Methods.

a. General. This section outlines data reduction methods used to quantitatively describe the agreement between AWOS measurements and corresponding collocated official observations. The two general statistical techniques used to compare AWOS with official data for each AWOS site, meteorological parameter, and case study are a correlation and regression analysis and a time-series analysis of differences (AWOS minus official). Also described are the procedures used in testing the statistical accuracy or significance of the computed statistics.

b. Correlation and Regression Analysis. The degree and type of relationship (or interdependence) between the AWOS and corresponding official observation was examined using linear correlation and regression analyses. In this subsection, the dependent and discrete random variables y and x are taken as being representative of the AWOS measurement and corresponding official observation, respectively.

The degree of linear dependence between AWOS and official data is determined through the estimation of the linear correlation coefficient. A general form of the sample linear correlation coefficient between the random variables x and y is given by:

$$r_{xy} = \frac{s_{xy}}{s_x s_y} , \tag{7}$$

where s_{xy} is the sample covariance between x and y, and s_x and s_y are their respective sample standard deviations. The correlation coefficient r_{xy} was computed using the calculation formula:

$$r_{xy} = \frac{N\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{[N\Sigma x_i{}^2 - (\Sigma x_i)^2]^{1/2} \cdot [N\Sigma y_i)^2 - (\Sigma y_i)^2]^{1/2}} , \tag{8}$$

where N is the number of data pairs. The foregoing equation is also known as the Karl Pearson product-moment correlation coefficient.

The range of the statistic r_{xy} is $-1.0 \leq r_{xy} \leq 1.0$. A strong relationship exists between x and y when the value of the correlation coefficient r_{xy} lies close to either interval bound (i.e., little scatter), while a weak relationship prevails as r_{xy} approaches zero (i.e., large scatter). Positive values of r_{xy} signify that larger values of y are correlated with larger values of x, while negative r_{xy} indicates that smaller values of y are associated with larger values of x. For the purpose of this study, a favorable relationship between x and y is found when their relationship is linear, strong, and positively correlated, i.e., $r_{xy} \rightarrow +1$.

TABLE 18. AWOS SITE SYSTEM AND SENSOR VALUES CUMULATIVE TOTAL TIME TO REPAIR VS CUMULATIVE NUMBER OF FAILURES

WeatherMeasure	AUO	HOU	EEN	MIE	PSP	SBP	GAL
System	$\frac{6.15}{5}$	$\frac{1.00}{1}$	$\frac{6.25}{3}$	$\frac{0.17}{1}$	$\frac{2.05}{2}$	$\frac{2.00}{3}$	$\frac{0.75}{1}$
Ceiling	NF	$\frac{2.50}{2}$	$\frac{1.00}{2}$	$\frac{0.25}{1**}$	$\frac{0.10}{1}$	NF	$\frac{10.00}{1}$
Visibility	NF	NF	$\frac{9.18}{12}$	NF	$\frac{3.00}{1}$	$\frac{1.17}{3}$	NF
Wind	NF	$\frac{3.00}{1}$	NF	NF	NF	NF	NF
Temperature	NF	NF	NF	$\frac{10.08}{2}$	NF	NF	NF
Dew Point	NF	NF	NF	$\frac{0.33}{1}$	NF	NF	NF
Precipitation	NF	$\frac{1.00}{1}$	$\frac{7.00}{2}$	$\frac{2.50}{2}$	NF	NF	NF
Altimeter	NF	$\frac{1.20}{1}$	$\frac{7.58}{2}$	NF	NF	NF	NF

Artais	DCA	DBQ	HUM	CMX	PWT	SAF	VDZ
System	$\frac{7.20}{18}$	$\frac{17.17}{14}$	$\frac{20.37}{54}$	$\frac{13.30}{48}$	$\frac{13.41}{39}$	$\frac{1.38}{5}$	$\frac{25.50}{6}$
Ceiling	$\frac{2.00}{1}$	$\frac{28.90}{6}$	*	$\frac{1.75}{1}$	$\frac{8.00}{1}$	NF	$\frac{7.00}{1}$
Visibility	NF	$\frac{2.40}{1}$	$\frac{0.72}{6}$	NF	$\frac{0.43}{1}$	NF	NF
Wind	NF	$\frac{0.25}{1}$	NF	$\frac{0.50}{1}$	NF	NF	$\frac{0^{SC}}{2}$
Temperature	NF	NF	NF	NF	NF	$\frac{1.20}{1}$	NF
Dew Point	*	$\frac{1.75}{2}$	$\frac{8.90}{4}$	$\frac{0.58}{1}$	$\frac{0^{SC}}{1}$	NF	$\frac{6.00}{1}$
Precipitation	*	NF	$\frac{3.80}{2}$	$\frac{1.00}{1**}$	NF	NF	NF
Altimeter	$\frac{0.50}{1}$	$\frac{4.00}{1}$	NF	$\frac{0.30}{1}$	NF	NF	NF

Note:
NF = No failure occurences
* = Failure occurred, but not resolved
** = Second failure occurred, but not resolved
SC = Self correcting, failure did not require repair time

TABLE 17. AWOS SITE SYSTEM AND SENSOR VALUES FOR CUMULATIVE MTTR

WeatherMeasure	AUO	HOU	EEN	MIE	PSP	SBP	GAL
System	1.23	1.00	2.08	0.17	1.02	0.67	0.75
Ceiling	NF	1.25	0.50	0.25**	0.10	NF	10.00
Visibility	NF	NF	0.76	NF	3.00	0.39	NF
Wind	NF	3.00	NF	NF	NF	NF	NF
Temperature	NF	NF	NF	5.04	NF	NF	NF
Dew Point	NF	NF	NF	0.33	NF	NF	NF
Precipitation	NF	1.00	3.50	1.25	NF	NF	NF
Altimeter	NF	1.20	3.79	NF	NF	NF	NF

Artais	DCA	DBQ	HUM	CMX	PWT	SAF	VDZ
System	0.40	1.23	0.38	0.28	0.34	0.28	4.25
Ceiling	2.00	4.82	*	1.75	8.00	NF	7.00
Visibility	NF	2.40	0.12	NF	0.43	NF	NF
Wind	NF	0.25	NF	0.50	NF	NF	0
Temperature	NF	NF	NF	NF	NF	1.20	NF
Dew Point	*	0.88	2.22	0.58	0	NF	6.00
Precipitation	*	NF	1.90	1.00**	NF	NF	NF
Altimeter	0.50	4.00	NF	0.30	NF	NF	NF

Note:
NF = No failure occurences
 * = Failure occurred, but not resolved
** = Second failure occurred, but not resolved

Similar to the analysis for MTBF, total period time was established, on a month by month basis, as 720 hours.

Hence, for computational purposes on a month by month basis, in general,

$$\text{MTTR} = \frac{\text{Total Time to Repair (hrs)}}{\text{Total Number of Failures}}$$

for any system or sensor.

MTTR was calculated monthly, as well as on a cumulative basis, for each system and sensor for the 10-month AWOS Demonstration Program. Mathematically, cumulative MTTR is expressed as follows:

$$\text{Cumulative MTTR} = \frac{\sum_{j=1}^{10} \text{Total Time to Repair (hrs)}}{\sum_{j=1}^{10} \text{Total Number of Failures}} \tag{6}$$

where j represents the number of monthly periods.

10. Cumulative MTTR Results. Table 17 provides matrix type presentations of cumulative MTTR results for the WeatherMeasure and Artais AWOS sites for the 10-month period. The symbol "NF", appearing as entries in various blocks of the two matrices, designates situations in which there were no occurrences of failure. Site system blocks contain a numerical value (in hours), while "NF's" are distributed differently in the site blocks for the seven sensors.

A single asterisk entry in three of the Artais site blocks denotes that each of the respective sensors experienced a failure, but these failures were not resolved by the end of the AWOS Demonstration Program. In these instances, cumulative MTTR's were not determinable. The double asterisk appearing in the Houghton precipitation sensor block signifies that this sensor experienced a second failure, but this failure was not resolved by the end of the AWOS demonstration period. The numeric entry in this block, however, represents the cumulative MTTR for this precipitation sensor attributable to the resolvement of an earlier failure which had occurred.

Table 18 affords supplementary type supporting data, in matrix type format, as to the actual values used in computing the corresponding WeatherMeasure and Artais cumulative MTTR's shown previously in table 17. In those instances where one or more failures occurred and were resolvable, the blocks of the two matrices contain ratios. The numerator in each instance represents the cumulative total time to repair; the denominator indicates the cumulative total number of failures. Division of the upper value by the lower value results, in all cases, in the cumulative MTTR values of table 17. Entries of "NF" and asterisks in table 18 retain the same meanings as in table 17.

TABLE 16. SYSTEM AND SENSOR FAILURE DIAGNOSES DISTRIBUTION CATEGORIES BY MANUFACTURER

Cause(s) of Failure/Corrective Action	S	C	V	W	T	D	P	A	Total
WeatherMeasure									
CPU fault/reset required	3								3
Defective module/replace	8	1				1		1	11
Power failure/replaced fuse	1								1
Erroneous data/clean sensor	1	1					1		3
Erroneous data/calibrate sensor		2	2					1	5
Short circuit/repair				1			1		2
Loose connection/repair					2		1		3
Sensor malfunction/repair-replace		2	1				1	1	5
Rack fault/reset required	2	1	12				1		16
Defective power supply/replace	1								1
Indeterminate/self correcting			1						1
Unresolved at end of test period		1							1
Total	16	8	16	1	2	1	5	3	52
Artais									
CPU fault/reset required	68							1	69
Defective module/replace	4	4	1						9
Power failure/reset			1			2			3
Erroneous data/clean sensor	2		6				2		10
Erroneous data/calibrate sensor	1	3		1		2		1	8
Short circuit/repair					1	2			3
Loose connection/repair	2							1	3
FDC comm error/reset	94								94
Hardware problem/repair	1	2					1		4
Erroneous data/reset	1	1		1		1			4
Erroneous data/defrost frozen unit				2					2
Fiber optic modem fault/reset	11								11
Indeterminate/self correcting						2			2
Unresolved at end of test period		1				1	2		4
Total	184	11	8	4	1	10	5	3	226

Note:

S = System	T = Temperature
C = Ceiling	D = Dew Point
V = Visibility	P = Precipitation
W = Wind	A = Altimeter

Two sets of tables are presented in this appendix. Table C-1 covers WeatherMeasure failures and table C-2 covers Artais failures. The format of these sets of tables are the same and essentially follow the format of table 12. However, they differ in the depth and scope of coverage required in the failure-by-failure accounting diagnosis process. Summary information is respectively tabulated regarding the cause(s) of the failure occurrence and corrective action taken to restore the item (system or sensor) to operation. In those instances in which no failures occurred for a sensor, "none" appears as an entry in the failure number tabular column. Further, failures that remained unresolved by the conclusion of the demonstration period are so indicated.

Table 16 lists in a matrix type format a consolidated summarization of the system and sensor failures by manufacturer for the 10-month AWOS demonstration period. Data relative to cause(s) of failure and corrective actions from appendix tables C-1 and C-2 were separately analyzed, reduced, and grouped into like failure diagnosis distribution categories. The respective categories appear in the first column of table 16. As will be noted, there are 12 distribution categories for WeatherMeasure and 14 for Artais, some of which have the same descriptive title, while others differ. Dissimilarities are attributed to the differences in the manufacturer's AWOS design and methods for providing corrective actions to restore operation.

The resulting numerical distribution by failure diagnosis category for system and each sensor is shown in the right-hand portion of the table. The predominant categories for WeatherMeasure are "Rack Fault/Reset Required" for visibility sensors (12) and "Defective Module/Replace" for system (8). With respect to Artais, the principle categories are system "FDC Comm Error/Reset" (94), system "CPU Fault/Reset" (68), and system "Fiber Optic Modem Fault/Reset" (11).

9. MTTR Analysis Methodology. MTTR refers to the time it takes maintenance personnel to perform repair actions to restore the system or sensor to full operation following a failure. Maintenance personnel and spare parts are presumed to be on site. Further, the time that the system or sensor is down or nonoperational excludes administrative downtime (i.e., the time it takes to detect the occurrence of a failure and all normal preventative maintenance time) and logistics downtime (i.e., travel time and acquisition time to acquire spare parts).

Specifically, MTTR includes the maintenance time repair actions to: (a) diagnose the failure; (b) remove the failed item (part, module, unit, assembly, etc.); (c) repair the item, if only repair is warranted; (d) replace the failed item with a spare, if warranted; and (e) verification to assure proper operation has been resumed.

MTTR was calculated for the system and each of the seven sensors at each of the 14 AWOS sites by means of the mathematical expression:

$$\text{MTTR} = \sum_{i=1}^{n} \frac{\text{Time to Repair Failure } i}{n} \tag{5}$$

where n is the number of failures during the time period.

The source of data used for the various no failure and one failure computations of the confidence limits of the true MTBF were the total operating times. The respective related total operating times, in hours, appear in the last row of the system and sensor tables of appendix B. The values for the various estimated MTBF's were extracted from the last column/last row entries of the respective appendix B tables, as applicable.

7. Overall System MTBF Results. Table 15 provides a summary composite listing of the cumulative operating times and number of failures for the respective WeatherMeasure and Artais Systems by site during the 10-month period of September 1983 - June 1984. Additionally, totally aggregate operating times and number of failures for each of the two manufacturer's systems are shown. Following customary, widely accepted practices, overall system MTBF's were computed by dividing the respective aggregate operating times by the aggregate number of failures. The calculated value of system MTBF for WeatherMeasure was found to be 3,107.54, and for Artais, 254.85.

TABLE 15. CUMULATIVE SYSTEM DATA BY MANUFACTURER BY SITE

WeatherMeasure	(Operating Hrs)	No. of Failures
AUO	6,811.17	5
HOU	7,199.00	1
EEN	7,096.00	3
MIE	7,196.93	1
PSP	7,197.95	2
SBP	7,055.58	3
GAL	7,164.00	1
Totals	49,720.63	16

Artais	(Operating Hrs)	No. of Failures
DCA	7,141.12	18
DBQ	6,277.40	14
HUM	6,562.88	54
CMX	7,001.37	48
PWT	6,730.02	39
SAF	7,156.22	5
VDZ	6,023.00	6
Totals	46,892.01	184

8. Failure Diagnosis. Appendix C provides a failure diagnosis summary of all failures occurring during the 10-month AWOS demonstration period. While table 12 affords a composite summary accounting for the distribution of failures in matrix form, appendix C extends the utility of table 12 by furnishing a chronological enumeration of all failure occurrences on a monthly basis.

TABLE 14. ESTIMATED MTBF VALUES AND CONFIDENCE LIMIT VALUES OF TRUE MTBF FOR ARTAIS

		DCA	DBQ	HUM	CMX	PWT	SAF	VDZ
System		397	448	122	146	172	1431	1004
Ceiling	L	1747	738	1690	1634	1704	3105	1419
	U	64500		62386	60325	62919	----	52387
Visibility	L	3097	1608	1091	3039	1744	3105	2748
	U	----	59371		----	64396	----	----
Wind	L	3098	1746	2849	1794	2942	3124	2880
	U	----	64460	----	66237	----	----	
Temp.	L	3098	2947	2860	3039	2943	1844	2613
	U	----	----	----	----	----	68090	----
Dewpoint	L	1555	3395	1575	1788	1731	3123	1246
	U	57434			66032	63904	----	46018
Precip.	L	1068	2946	3285	420	2943	3124	2748
	U	39453	----			----	----	----
Altimeter	L	1851	1850	3118	1851	3124	3124	2947
	U	68339	68293	----	68341	----	----	----

NOTE:
L = Lower Confidence Limit of True MTBF
U = Upper Confidence Limit of True MTBF

TABLE 13. ESTIMATED MTBF VALUES AND CONFIDENCE LIMIT VALUES OF TRUE MTBF FOR WEATHERMEASURE

	AUO	HOU	EEN	MIE	PSP	SBP	GAL
System	1362	L 1851 U 68334	2365	L 1850 U 68314	3599	2352	L 1842 U 68002
Ceiling	L 2975 U ----	3296	3599	742	L 1851 U 68332	L 3123 U ----	L 1711 U 63189
Visibility	L 2984 U ----	L 3124 U ----	594	L 3123 U ----	L 1850 U 68303	2398	L 3108 U ----
Wind	L 3106 U ----	L 1850 U 68315	L 3079 U ----	L 3123 U ----	L 3123 U ----	L 3061 U ----	L 3108 U ----
Temp.	L 3094 U ----	L 3124 U ----	L 3079 U ----	3500	L 3123 U ----	L 3061 U ----	L 3108 U ----
Dewpoint	L 3094 U ----	L 3124 U ----	L 3079 U ----	L 1849 U 68292	L 3123 U ----	L 3061 U ----	L 3108 U ----
Precip.	L 3106 U ----	L 1851 U ----	3584	3358	L 3123 U ----	L 3061 U ----	L 3108 U ----
Altimeter	L 3124 U ----	L 1844 U 68095	3572	L 3124 U ----	L 3124 U ----	L 3124 U ----	L 3124 U ----

NOTE:
L = Lower Confidence Limit of True MTBF
U = Upper Confidence Limit of True MTBF

b. <u>Time Series Plots</u>. The time series plots depict the residuals (AWOS minus official) as a function of time over the 10-month study. These time series plots were very useful in the identification and editing of anamolous data points in the raw data. Time series plots for the eight meteorological variables are given for DCA and HOU in figures D-1 through D-10 of appendix D. As additional information, the sample size N, bias value, rms value, and reliability index are annotated in each time series plot. The dotted horizontal lines represent the prescribed tolerance interval for reliability index computation (see table 20).

c. <u>Scattergrams</u>. A scattergram (or scatter plot) is a practical way to graphically display the results of a correlation and regression analysis. Scattergrams were constructed by plotting the AWOS measurements against the corresponding observed values. In general, the degree of correlation is seen by the relative scatter in these data, while the particular relationship between the AWOS and observed values is typified by the trend in these data points. Scattergrams for the eight meteorological sensors at DCA and HOU are displayed in figures D-11 through D-20 in appendix D. Note that each datum point in the scattergrams may represent more than one event due to the discrete quantizing intervals of the data. As a result, scattergrams of cloud height and visibility may be deceiving because of the relatively small number of reportable increments. The number of data pairs N, the sample linear correlation coefficient "R," and the slope "A" and y-intercept "B" of the linear regression equation $y = Ax + B$, where y is the AWOS measurement and x is the corresponding official value, are indicated in each scattergram. This linear regression equation is depicted in each scattergram as the best-fit straight line imposed through these data points. A perfect relationship is shown as the dotted line at 45°.

d. <u>Histograms</u>. Histograms provide a graphical means of showing how well the probability distribution of residuals approaches a normal or Gaussian distribution. Relative frequency histograms show the number of occurrences (normalized relative to total sample size) a certain value of the residual takes on within the sample period. The relative cumulative frequency histogram, on the other hand, is a more useful tool in analyzing the probability distribution of residuals since we are normally interested in the magnitude (absolute value) of the errors.

Histograms of residual errors for eight meteorological parameters at DCA and HOU are presented in figures D-21 through D-30 in appendix D. Each histogram shows both the relative frequency and relative cumulative frequency probability distributions as a function of the residual class mark (or midpoint) denoted on the x-axis. The relative frequency distribution is depicted by the shaded rectangular boxes corresponding to the y-axis values on the left-hand side of the plot. Each box is proportional to the percentage of residual differences which fall within that particular class interval. The relative cumulative frequency distribution is represented by the dark solid line extending from the lower-middle to upper-right portion of the plot. Relative cumulative frequency values corresponding to this line are given on the y-axis at the right-hand side of the plot. The relative cumulative frequency indicates the percentage of the time that the absolute value of the residual error was less than or equal to that of the class mark.

In each histogram, the residual sample size N, bias value, rms value, and reliability index are given. A normal probability function was fitted to the sample distribution for comparison. This function, which is depicted by the smooth dotted line in the figures, was applied based on the sample mean value and standard deviation of the data. The vertical dotted line represent the prescribed tolerance interval used for reliability index computation (see table 20). Hence, the value of the relative cumulative frequency at the intersection of the vertical dotted line is representative of the reliability index.

3. Results.

a. General. Detailed results of the AWOS versus official comparison analysis for each meteorological parameter and AWOS site are given in appendix D. The results are summarized according to overall AWOS performance, the two system contractors, and the sensor types.

A total of 22,992 pairs of hourly AWOS and official reports were compared and analyzed. The statistics presented in this section are based on averages weighted according to individual sample size in order to account for the different sample sizes for each parameter and site. Sample sizes less than 10 were disregarded.

b. Sky and Ceiling.

(1) Background. A considerable effort was devoted to the sky and ceiling analysis since the state of the sky is most critical to aviation safety. Before a straightforward comparison and performance evaluation can be made based on statistics, it is important to point out the different methods by which sky and ceiling reports are prepared by AWOS and official observers.

AWOS employs a single-sensor lidar cloud height indicator (CHI) called a laser ceilometer. Artais Systems use German-built Impulsphysik ceilometers, while WeatherMeasure systems use Japanese-built Meisei ceilometers. These laser ceilometers detect the height of individual cloud elements passing directly over the sensor up to a height of 5,000 feet above the surface. A 30-minute time history of ceilometer data, updated every 30 seconds, is processed every minute by a cloud algorithm which reduces the data using a hierarchial clustering technique. Output from the algorithm is the height and cover for up to three cloud layers in a standard surface aviation weather observation format for sky and ceiling.

Official observations of sky and ceiling follow the procedures in the Federal Meteorological Handbook No. 1 (FMH-1). The height and cover of each cloud layer is estimated by a certified weather observer who visually surveys the whole sky from horizon to horizon. The degree of subjectiveness and bias in the cloud height and cover estimates differs from one observer to the next. At many weather stations, official observations of sky and ceiling are conducted with the aid of a rotating beam ceilometer (RBC). The RBC consists of a rotating high-intensity light transmitter and a vertically-pointing light receiver which are normally separated about 400 or 800 feet apart. Using a simple triangulation principle, the RBC measures the height of individual cloud elements passing directly over the receiver. The nominal height range of the RBC is about 10 times the length of its baseline. RBC data is output to a strip chart and visually analyzed by a weather observer. The height of each cloud layer is ordinarily readily discernible; however, cloud cover estimates from RBC strip charts are usually supported by visual inspection of the sky.

An outline of the different systems by which AWOS and official observations of sky and ceiling reports were obtained for each AWOS site is given in table 21. The official measurement type indicated in this table represents the most common method used in determining sky and ceiling at that site.

In summary, it is important to compare and evaluate AWOS ceilometer performance in light of the accuracy of subjectiveness of the AWOS and official observations. One advantage of the human observer over AWOS is that the observer can scan the whole sky. These official observations of cloud height and cover, however, are subjective estimates sensitive to the human element of bias and variability. RBC measurements analyzed by official observers provide the least subjective means of determining sky and ceiling, particularly for cloud height. The accuracy of AWOS sky and ceiling reports depends on the accuracy of the ceilometer in detecting cloud elements, and on the efficiency of the cloud algorithm to process ceilometer data obtained from sampling a fixed point in space. Since the algorithm requires a sufficiently long sample time to derive cloud cover, AWOS response to rapidly changing cloud conditions may be compromised. This condition is corroborated by reports from field technicians and pilots. Consequently, the Technical Center is currently conducting a study to improve the responsiveness of the cloud algorithm.

TABLE 21. CLOUD HEIGHT SENSOR SETUP

Site	AWOS Ceilometer	Official Measurement Type	RBC Baseline (ft)	Distance to AWOS (ft)
CMX	Impulsphysik	EST	----	3300
DBQ	Impulsphysik	RBC	388	1320
DCA	Impulsphysik	RBC	350	660
HUM	Impulsphysik	EST	----	3000
PWT	Impulsphysik	EST	----	3500
SAF	Impulsphysik	RBC	400	500
VDZ	Impulsphysik	EST	----	1980
EEN	Meisei	EST	----	6000
GAL	Meisei	RBC	400	200
HOU	Meisei	RBC	550	2000
MIE	Meisei	RBC	800	1320
PSP	Meisei	EST	----	1320
SBP	Meisei	EST	----	990

(2) Cloud Layer Number. For each pair of sky and ceiling reports, the number of reported AWOS cloud layers was compared with the corresponding number of layers reported by the official observer. This was carried out by disregarding the following irrelevant situations: (a) clouds above 5,000 feet; (b) joint occurrences of clear below 5,000 feet; and (c) cloud height and cover of the layers. Results of the analysis are presented for each AWOS site in table D-1. A summary of these results by system and sensor type are outlined in table 22. These tables show the distribution of N cloud layer number difference (AWOS minus official) according to seven discrete classes. The number of joint occurrences of clear skies below 5,000 feet not included in this analysis is denoted by N_c.

TABLE 22. CLOUD LAYER NUMBER RESULTS

System	N_c	N	Distribution in Percent						
			(N_A-N_O) -3	-2	-1	0	1	2	3
AWOS	10,131	10,454	0	3	30	37	21	7	1
Impulsphysik	3,984	4,529	0	3	31	45	17	4	0
Meisei	6,147	5,925	0	4	30	31	24	10	2

About one-half of the 20,585 pairs of sky and ceiling reports collected in this study were joint occurrences of clear below 5,000 feet. In regards to the remaining half of the sample, AWOS (Artais and WeatherMeasure data combined) was in perfect agreement with the number of official reported cloud layers 37 percent of the time. When a layer difference of one layer or less is considered, AWOS agreed with the official 88 percent of the time.

Impulsphysik ceilometers generally performed better than the Meisei ceilometers. Impulsphysik ceilometers were in perfect agreement with the official observations 14 percent more often than Meisei ceilometers. The agreement to within one cloud layer was 93 and 85 percent for Impulsphysik and Meisei, respectively. The former system underestimates the number of cloud layers 13 percent more often than it overestimates, while the latter system overestimates the cloud layer number two percent more often than it underestimates it. Impulsphysik ceilometers display even better performance when the abnormally poor results from VDZ are disregarded. A preliminary investigation revealed no appreciable difference in the foregoing results when AWOS data were compared with official observations differentiating between sites with and without RBC's.

(3) Obscuration Comparison. The frequency of occurrence of sky obscurations were compared between AWOS and official for four case studies. A total obscuration is defined in the FMH-1 as a surface-based obscuring phenomena that hides all of the sky. A partial obscuration is when 0.1 to 0.9 of the sky is hidden. Such phenomena commonly result from precipitation, fog, smoke, and other weather phenomena that substantially reduce vertical visibility. There is no known sensor which quantitatively measures the extent

of a partial obscuration, total obscuration, or vertical visibility. Consequently, the AWOS cloud algorithm estimates obscurations using a combination of cloud measurements, horizontal visibility, and air temperature.

Special cases in which AWOS did not report an obscuration while the official observer reported a partial obscuration were disregarded from the analysis. This was done because AWOS ceilometers point vertically; whereas, official observers survey the whole sky.

Results are presented in table D-2 and summarized in table 23. The four case studies are according to official reports of prevailing weather. AWOS generally reported more obscurations than official, particularly when there was no precipitation or fog. When no precipitation or fog occurred, AWOS falsely reported an obscuration 53 percent of the time while the official observer did not report even a partial obscuration. This large number of false detections by AWOS is probably attributed to the dependence of the AWOS cloud algorithm on AWOS visibilities less than 2 miles. Overall, AWOS agreed with the official 62 percent of the time. Agreement during precipitation and fog events was slightly better where AWOS was in joint agreement with the official observations 71 and 67 percent of the time, respectively.

TABLE 23. SKY OBSCURATION

			Distribution in Percent		
Case	System	N	AWOS No Official Yes	Joint Occurrence	AWOS Yes Official No
Overall	AWOS	1009	17	62	21
	Impulsphysik	684	17	62	21
	Meisei	325	18	61	22
No Precipitation or Fog	AWOS	173	12	35	53
	Impulsphysik	146	14	34	53
	Meisei	27	4	44	52
Precipitation	AWOS	470	20	71	10
	Impulsphysik	385	19	72	9
	Meisei	85	24	66	11
Fog	AWOS	471	17	67	16
	Impulsphysik	257	16	67	18
	Meisei	214	19	68	14

(4) Ceiling Occurrence. The frequency of occurrence of joint reports of a ceiling between AWOS and official observations was examined for four case studies. A ceiling is defined in the FMH-1 as the height of the lowest cloud layer or obscuring phenomena aloft which is at least broken or overcast in cover (i.e., 0.6 - 1.0 total sky cover); or, the vertical visibility into a surface-based obscuring phenomena that hides all the sky. The comparison was carried out by counting the joint frequency of occurrence of ceilings and clear skies below 5,000 feet. As a result, this ceiling occurrence analysis can be considered as a gross cloud cover comparison. Scattered cloud layers and the height difference between ceilings is not taken into account.

Results of the comparison are given by AWOS site and case study in table D-3. These results are summarized for the AWOS systems and four case studies in table 24. A general feature of the results is the marked increase in AWOS performance during degraded weather conditions of precipitation and fog. AWOS and official jointly reported ceilings 60 percent of the time when there was no precipitation or fog, and about 89 percent of the time when there was precipitation or fog. Overall results during precipitation are very similar to those during fog. An interesting aspect of the results is the consistently better performance of the Impulsphysik ceilometers over the Meisei sensors. Joint occurrences of AWOS ceilings and official ceilings during conditions of no precipitation and fog was strikingly different at 74 and 45 percent for Impulsphysik and Meisei, respectively.

During precipitation and fog events, both ceilometers performed significantly better, but Impulsphysik performance was about 11 percent better than Meisei. An important point is that during poor conditions of precipitation or fog when there is an official report of a ceiling, Meisei erroneously reports clear skies about 13 percent more often than Impulsphysik.

TABLE 24. CEILING OCCURRENCE

Case	System	N	Distribution in Percent: AWOS Clear Official Ceiling	Joint Ceilings	AWOS Ceiling Official Clear
	AWOS	5345	18	70	13
Overall	Impulsphysik	2779	11	85	4
	Meisei	2566	25	53	22
No Precipitation or Fog	AWOS	2421	24	60	16
	Impulsphysik	1256	19	74	7
	Meisei	1165	30	45	25
	AWOS	1504	9	88	3
Precipitation	Impulsphysik	1042	5	93	2
	Meisei	462	19	75	5
	AWOS	1473	7	89	4
Fog	Impulsphysik	822	2	96	3
	Meisei	651	13	81	6

(5) Cloud Height. A cloud height analysis was conducted by comparing the height difference of the official ceiling with the height of the nearest AWOS scattered, broken, or overcast layer. This was carried out for seven case studies and according to RBC measured versus estimated official ceilings. The results of the analysis for each site are given in table D-4. In these tables only measured official ceilings were considered for the six RBC sites. A summary of the results is given by system in table 25. In this table the AWOS summaries consider all estimated and RBC measured official ceilings. On the other hand, summaries by system contractor (i.e., ceilometer type) are based solely on measured ceilings obtained at official RBC sites.

TABLE 25. CLOUD HEIGHT

Case	System	N	r	$\bar{d}$	s	rms	RI
Overall	AWOS	3901	0.75	-1	821	895	63
	Impulsphysik	811	0.88	-1[illegible]2	466	488	77
	Meisei	1125	0.67	377	965	1044	68
Ceiling > 1500 ft	AWOS	1445	0.52	-233	980	1106	54
	Impulsphysik	224	0.58	-220	790	834	64
	Meisei	379	0.51	258	844	899	61
Ceiling ≤ 1500 ft	AWOS	2449	0.59	136	612	676	68
	Impulsphysik	587	0.84	-85	227	245	83
	Meisei	746	0.41	437	1002	1094	71
No Precipitation or Fog	AWOS	1549	0.77	70	739	781	65
	Impulsphysik	228	0.92	43	376	400	80
	Meisei	477	0.71	282	779	838	65
Precipitation	AWOS	1324	0.55	-232	819	982	53
	Impulsphysik	371	0.70	-264	569	626	68
	Meisei	221	0.59	287	857	928	66
Fog	AWOS	1392	0.65	69	687	746	73
	Impulsphysik	424	0.86	-118	330	352	84
	Meisei	442	0.49	253	908	947	78
AWOS and Official Ceiling	AWOS	2476	0.84	-125	551	601	71
	Impulsphysik	662	0.88	-124	421	445	79
	Meisei	561	0.93	112	324	343	85

Classification by case studies is based on the official reports. For the purposes of this study, an official ceiling of 1,500 feet is used to differentiate between low and high ceilings.

The seventh case study is based on a sample when the AWOS cloud layer nearest to the official ceiling is, in fact, an AWOS ceiling. This subset of the overall case study shows that 63 percent of the time AWOS cloud layer closest to the official ceiling is an AWOS ceiling. Corresponding figures for Impulsphysik and Meisei are 82 and 50 percent, respectively. These numbers indicate a better overall ceiling detection capability for Impulsphysik than Meisei.

Overall Impulsphysik and Meisei relative and cumulative frequency histograms of cloud height differences are given for official high-ceiling cases in figure 12. Corresponding histograms for official low-ceiling cases are in figure 13.

The overall AWOS reliability index and rms value for cloud height is 63 percent and 895 feet, respectively. Essentially, all of the rms is attributed to the variance between AWOS and official cloud height differences. Based on the rms value, AWOS accurately detects the height of low clouds about 64 percent better than high clouds. AWOS performance during precipitation events is about 12 percent less than those cases when precipitation did not prevail, and 10 percent less than the overall cases. During fog, in particular, AWOS agreement was better than all the other case studies (i.e., rms value and reliability index of 746 feet and 73 percent, respectively).

Based on RBC comparisons, Impulsphysik ceilometers were clearly better performers than the Meisei ceilometers. This finding was noted for every case study and statistic analyzed except for the particularly bad performance of the VDZ site. Impulsphysik ceilometers display better correlations, smaller bias values, and less variance than the Meisei ceilometers. The overall performance of these sensors, according to their rms values, is 488 and 1,044 feet for Impulsphysik and Meisei, respectively. An attractive feature of the Impulsphysik ceilometer is their far superior performance over the Meisei ceilometer when low official ceilings or fog prevails. In fact, the average rms value and reliability index value during these weather events is about 299 feet and 84 percent for Impulsphysik as opposed to 1,021 feet and 75 percent for Meisei. Performance of the Impulsphysik ceilometers appear even more favorable when the notably poor VDZ results are excluded.

When the results are further examined in terms of aviation safety, Impulsphysik ceilometers appear to be more suitable than Meisei ceilometers. Cloud height differences for Impulsphysik are favorably inclined to be more conservative than Meisei. Bias values of the Impulsphysik sensors are systematically negative and smaller in absolute value, while Meisei ceilometers typically have positive bias values with larger absolute values. This means that Impulsphysik agreeably underestimates cloud height, while Meisei overestimates cloud height. Furthermore, the Impulsphysik underestimates are regularly smaller in magnitude than the Meisei overestimates.

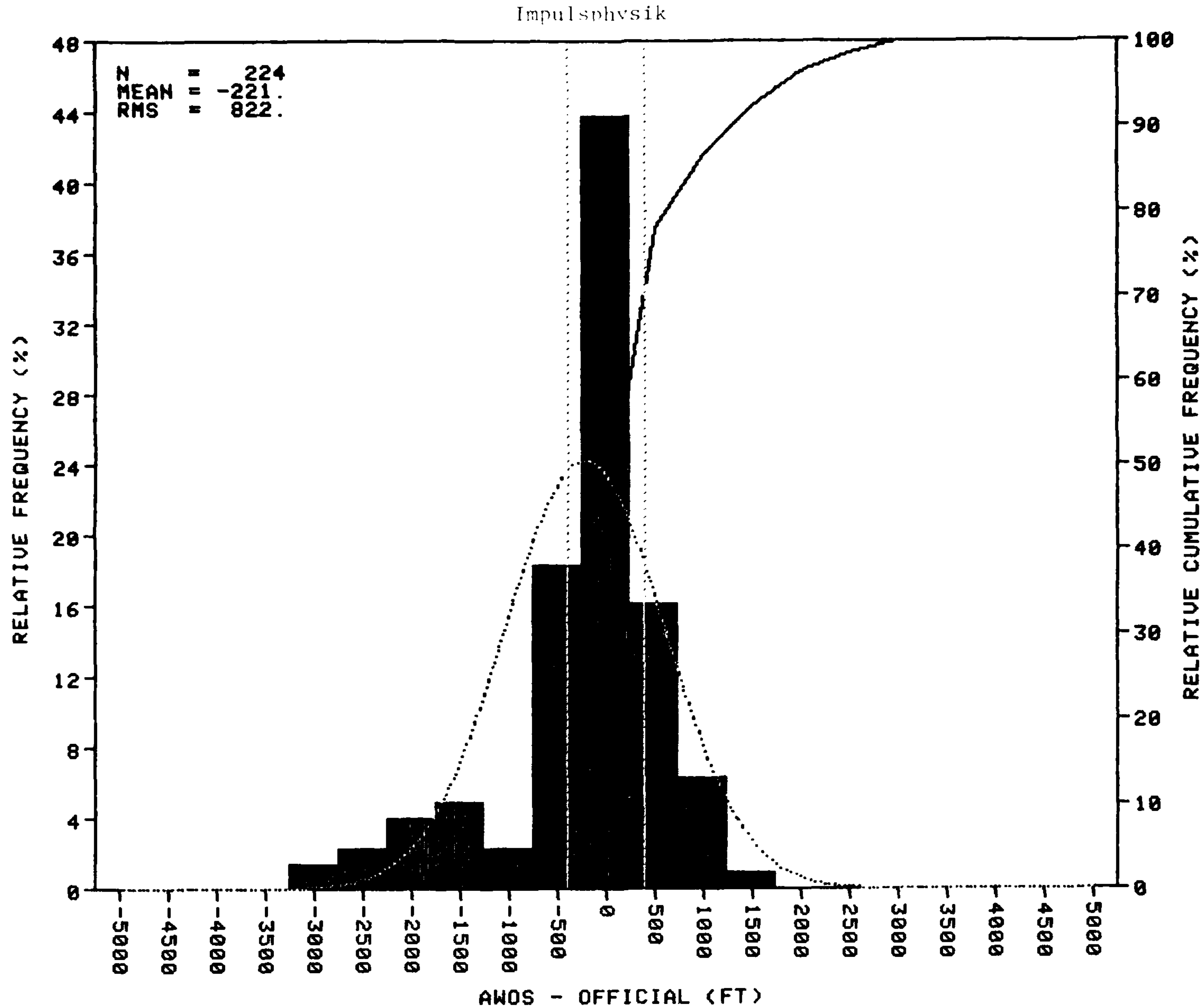

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FIGURE 12. CLOUD HEIGHT DIFFERENCE HISTOGRAMS FOR CEILOMETERS WHEN OFFICIAL CEILING IS GREATHER THEN 1,500 FEET (SHEET 1 OF 2)

Meisei

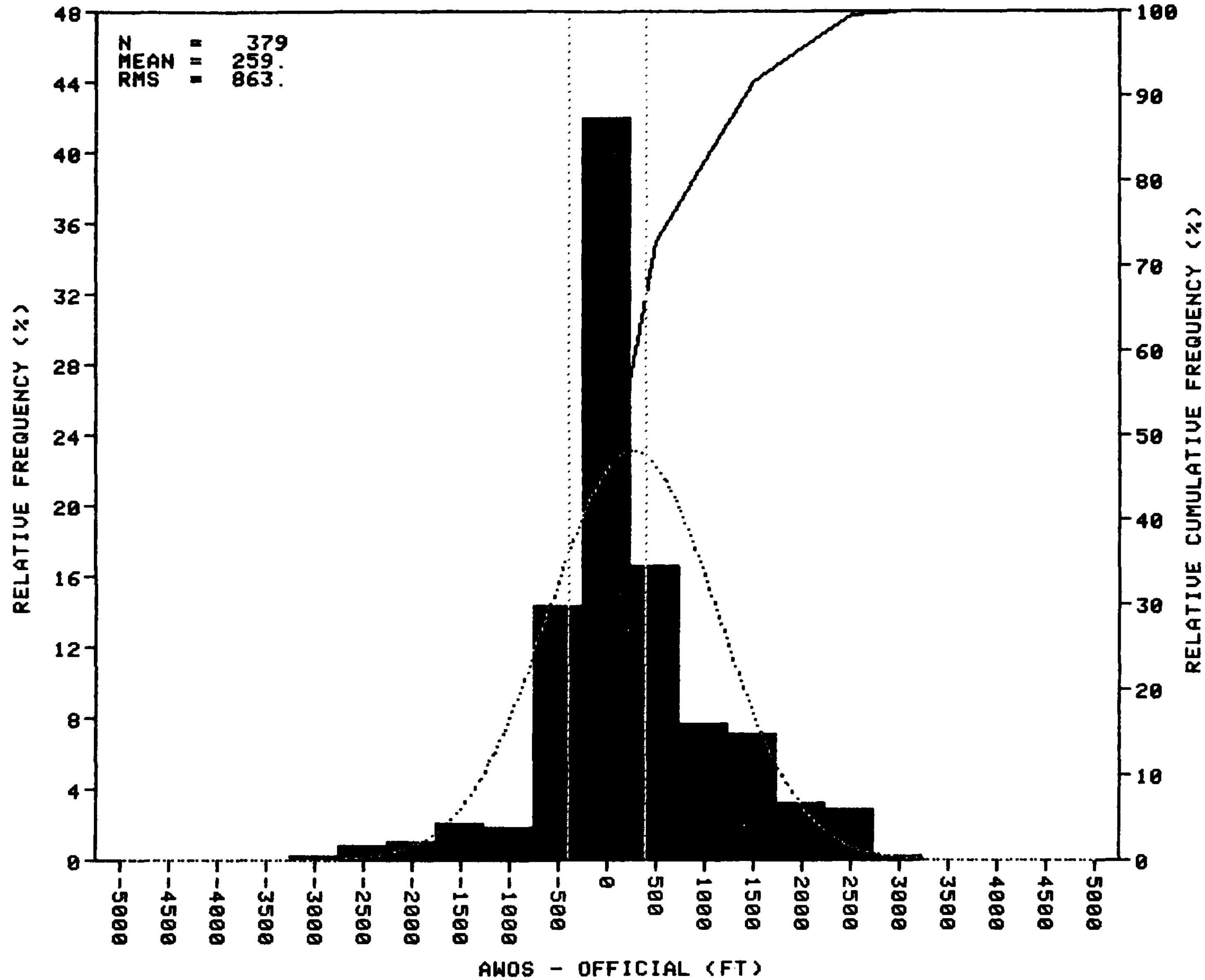

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FIGURE 12. CLOUD HEIGHT DIFFERENCE HISTOGRAMS FOR CEILOMETERS WHEN OFFICIAL CEILING IS GREATHER THAN 1,500 FEET (SHEET 2 OF 2)

Impulsphysik

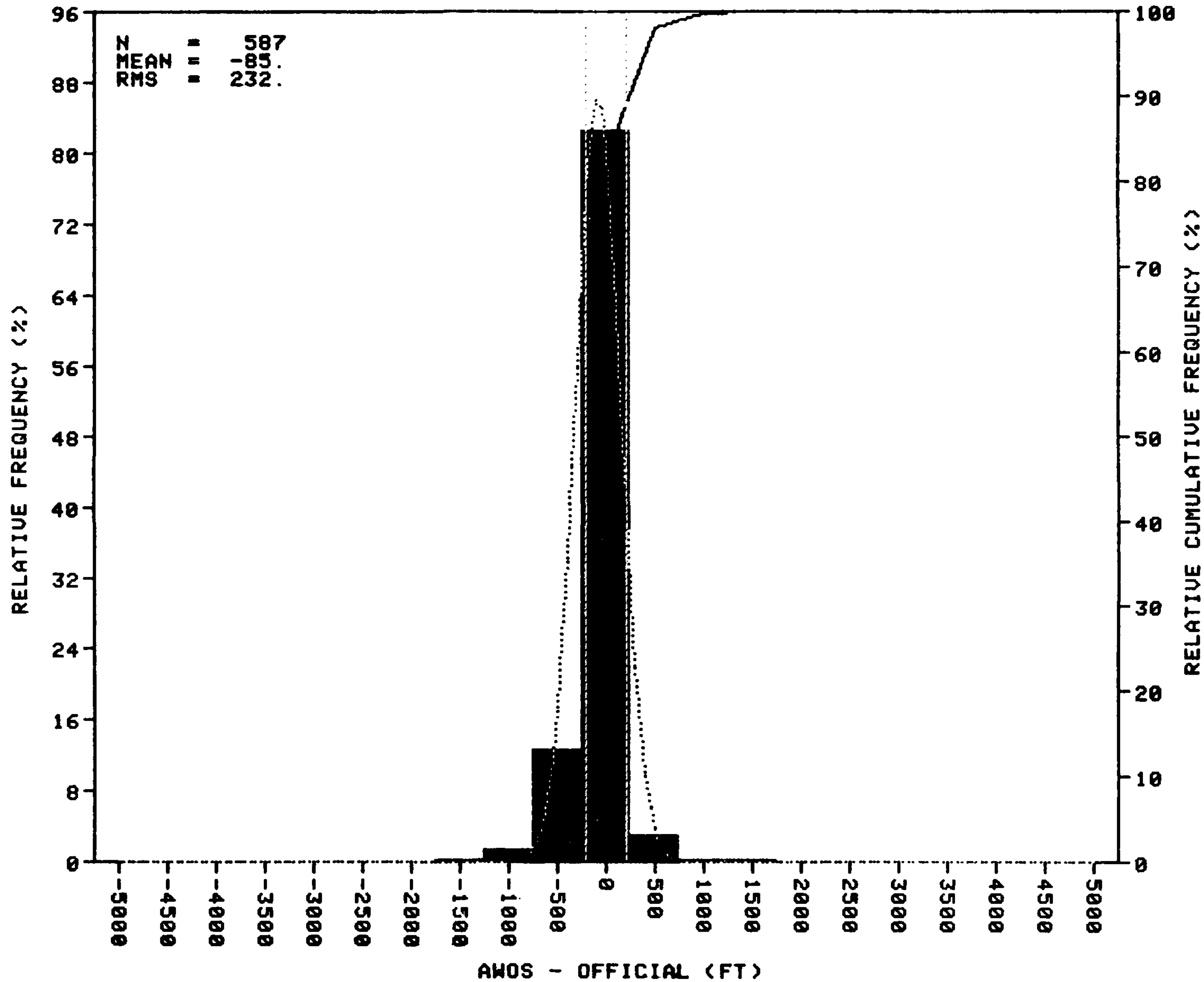

FIGURE 13. CLOUD HEIGHT DIFFERENCE HISTOGRAMS FOR CEILOMETERS WHEN OFFICIAL CEILING IS 1,500 FEET OR LESS (SHEET 1 OF 2) 84-20-13a

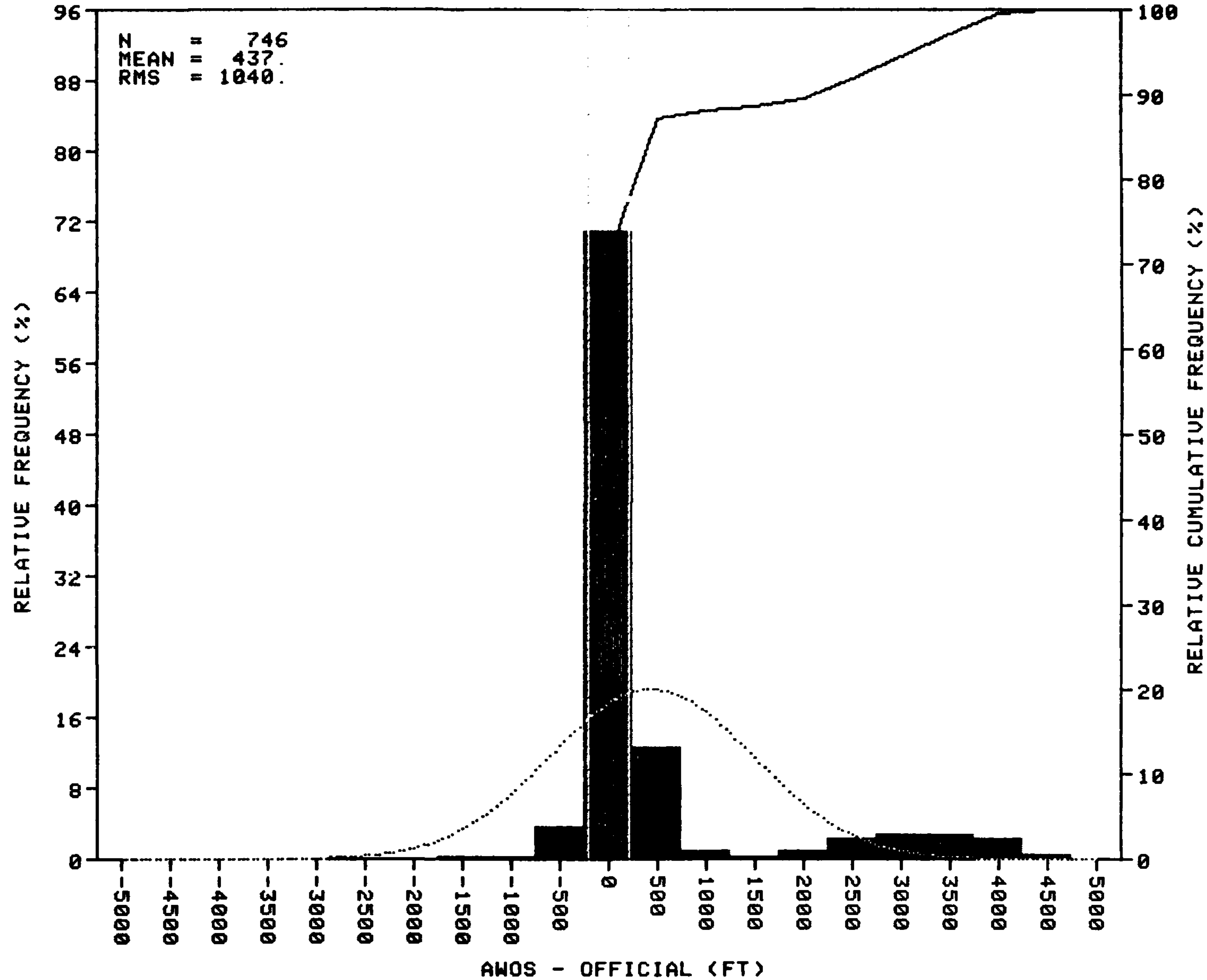

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FIGURE 13. CLOUD HEIGHT DIFFERENCE HISTOGRAMS FOR CEILOMETERS WHEN OFFICIAL CEILING IS 1,500 FEET OR LESS (SHEET 2 OF 2)

c. Visibility.

(1) General. The different methods by which AWOS and official visibilities are determined limit, to a certain degree, the objectivity of a comparison based on sample statistics. Then, in order to adequately evaluate AWOS visibility performance, it is important to point out the different visibility measurement techniques used by AWOS and official observers.

AWOS measures touchdown-zone visibility using single-sensor visibility devices located about 6 feet above ground. Four different visibility sensors were used in the AWOS Demonstration Program. These sensors are denoted throughout for convenience as: (a) 1,000-foot baseline transmissometer (T(1000)); (b) forward scatter (FWDSCAT); (c) backscatter (BCKSCAT); and (d) 492-foot baseline transmissometer (T(492)). Artais sites use either a FWDSCAT sensor or a T(1000), while WeatherMeasure sites use either a BCKSCAT device or a T(492). Because the AWOS visibility sensors sample a relatively small volume of air, AWOS visibilities are essentially local measurements sensitive to localized obscuring phenomena such as ground fog, fog banks, and blowing snow.

A prevailing visibility is, by definition, an official observation of visibility. To obtain the airport prevailing visibility, an observer subjectively integrates visual ranges through all azimuthal sectors around the point of observation. Individual visual ranges are estimated by examining a network of visibility markers located around the airport. The number, type, and spacing of visibility markers are usually nonuniformly distributed and differ from one airport to the next. Then, the bias and variability of estimating prevailing visibility obviously differs depending on the observer, prevailing weather conditions, and airport. Official prevailing visibilities are representative of an average visibility over a much larger area than AWOS, especially when the official observer is considerably elevated (e.g., in a control tower). Localized obscuring phenomena detected by AWOS visibility sensors may be averaged-out by the observers prevailing visibility, especially when AWOS is located at some distance from the observer. The range and reportable increment of visibility for AWOS and official observations is depicted in figure 14.

In view of the varying and different resolution scales for AWOS and official reportable visibility increments and distributions of visibility markers, the sensor functional requirement of ± 2 increments is not considered an appropriate choice for reliability index estimation. Consequently, a reliability index of 60 percent was adapted as a basis for judging AWOS visibility sensor performance.

A summary of the AWOS and official visibility systems is outlined in table 26. This table gives the height of the official observer above ground and the distance of the observer to AWOS. Numbers in parentheses are the heights of control towers from which, according to the FMH-1, visibilities of less than 4 miles are reported.

(2) Frequency Distribution. Since AWOS reportable visibility increments extend up to 5 miles, the first step in the analysis was to categorize AWOS and official visibility data into basic classes of visibility greater than 5 miles, and discrete visibilities less than or equal to 5 miles. This was done for each AWOS site, sensor, and case study by forming a joint

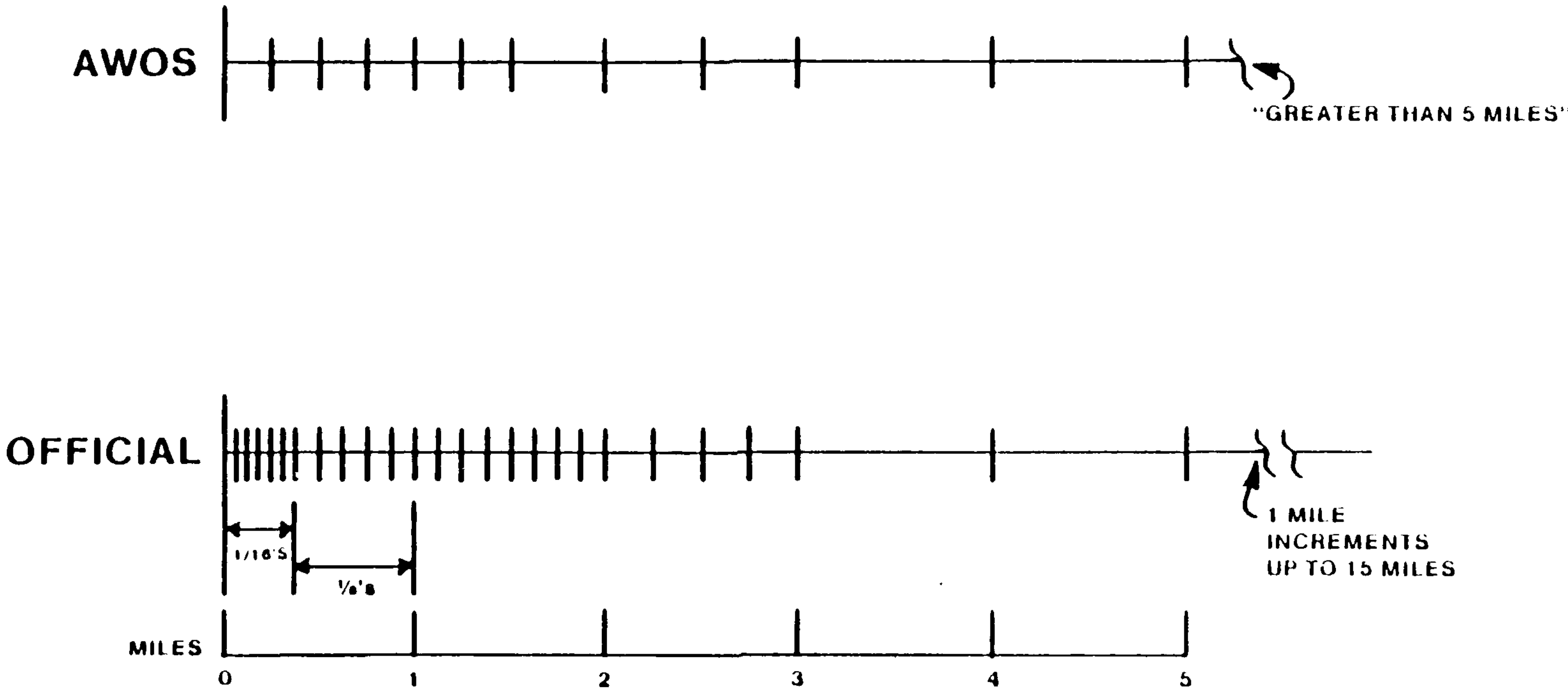

FIGURE 14. AWOS AND OFFICIAL REPORTABLE VISIBILITY INCREMENTS

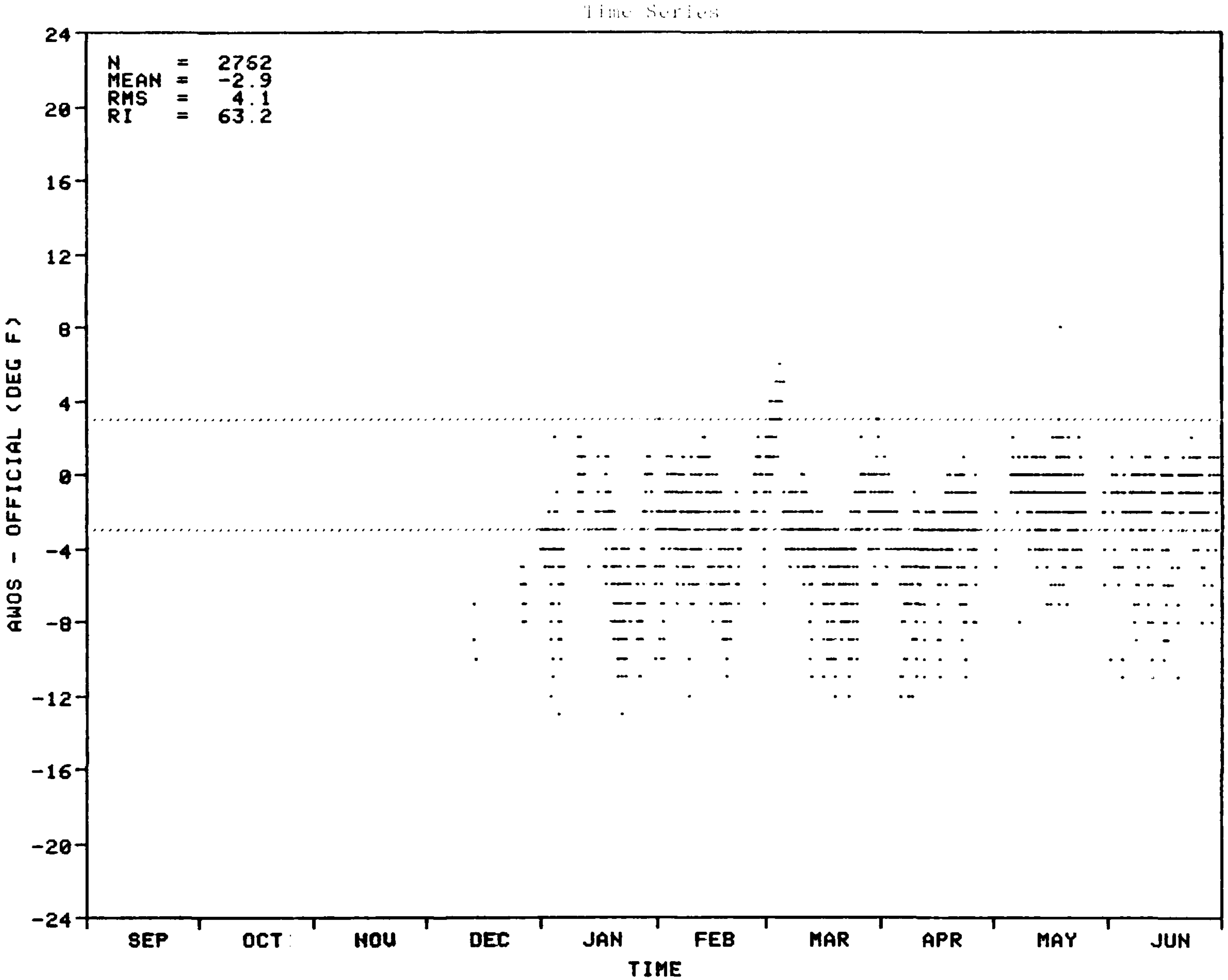

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FIGURE 19. GALENA TEMPERATURE DIFFERENCE (SHEET 1 OF 2)

Detailed results of the visibility analysis for each AWOS site and case study are presented in table D-6 in appendix D. This table shows that the relatively small sample size (N=319) of the T(1000) is based on data from DBQ and PWT. Most of these data were from DBQ which showed one of the best overall sensor results, while data from PWT displayed the least reliable overall visibility sensor performance. It is relevant to point out that the T(1000) sensors were, at times, subjected to alignment and stability problems as a result of shifting and wobbly sensor foundations. These problems, in turn, normally affect sensor bias and variance values in the visibility analysis.

(4) Temperature. Results of the dry-bulb temperature analysis, categorized according to individual AWOS site, is presented in table D-7. Sites at HUM and SBP were not included in the comparison since official observers at these sites did not take temperature readings. Official temperature data from PSP was automatically eliminated from the analysis since it was found that the official temperature sensor was poorly sited and exposed. The acceptance of AWOS temperature sensor as functional requires an rms error within 3 °F.

The statistics presented in the table are all significant at the 95 percent confidence level. This is a result of the large sample size and relatively good agreement between AWOS and the official observer (i.e., strong correlation and small variance). The best performance (rms = 1.0 °F) was exhibited at the HOU WeatherMeasure site which also had the largest sample size, 4,428.

Marginal performance was found for the WeatherMeasure site at GAL which had rms values of 4.1 °F and a reliability index of 63 percent. Examination of the GAL temperature time series shown in figure 19 indicates sporatic sensor performance over the experiment. A large bias value of about -3 °F contributed to most of the difference. Close inspection of the GAL temperature scattergram in figure 20 shows that the agreement between AWOS and official starts to fall-off at subzero temperatures. The AWOS temperature sensor accuracy based on factory test rms error sensor functional requirements is 1 °F for -40 °F to +120 °F and 2 °F for -60 °F to -40 °F. This accuracy tolerance does not fully account for the consistent 4 °F to 5 °F underestimation by AWOS of temperatures below -30 °F. The cause of the observed error for subzero temperatures is indeterminant at this time since the accuracy of the official temperature sensor is unknown.

A summary of the results is given by AWOS type in table 29. An overall AWOS temperature difference histogram is presented in figure 20.

TABLE 29. TEMPERATURE

System	N	r	$\bar{d}$	s	rms	RI
AWOS	16503	1.00	-0.9	1.7	2.0	91
Artais	7442	1.00	-0.7	1.5	1.7	96
WxMeasure	9061	1.00	-1.0	1.8	2.2	87

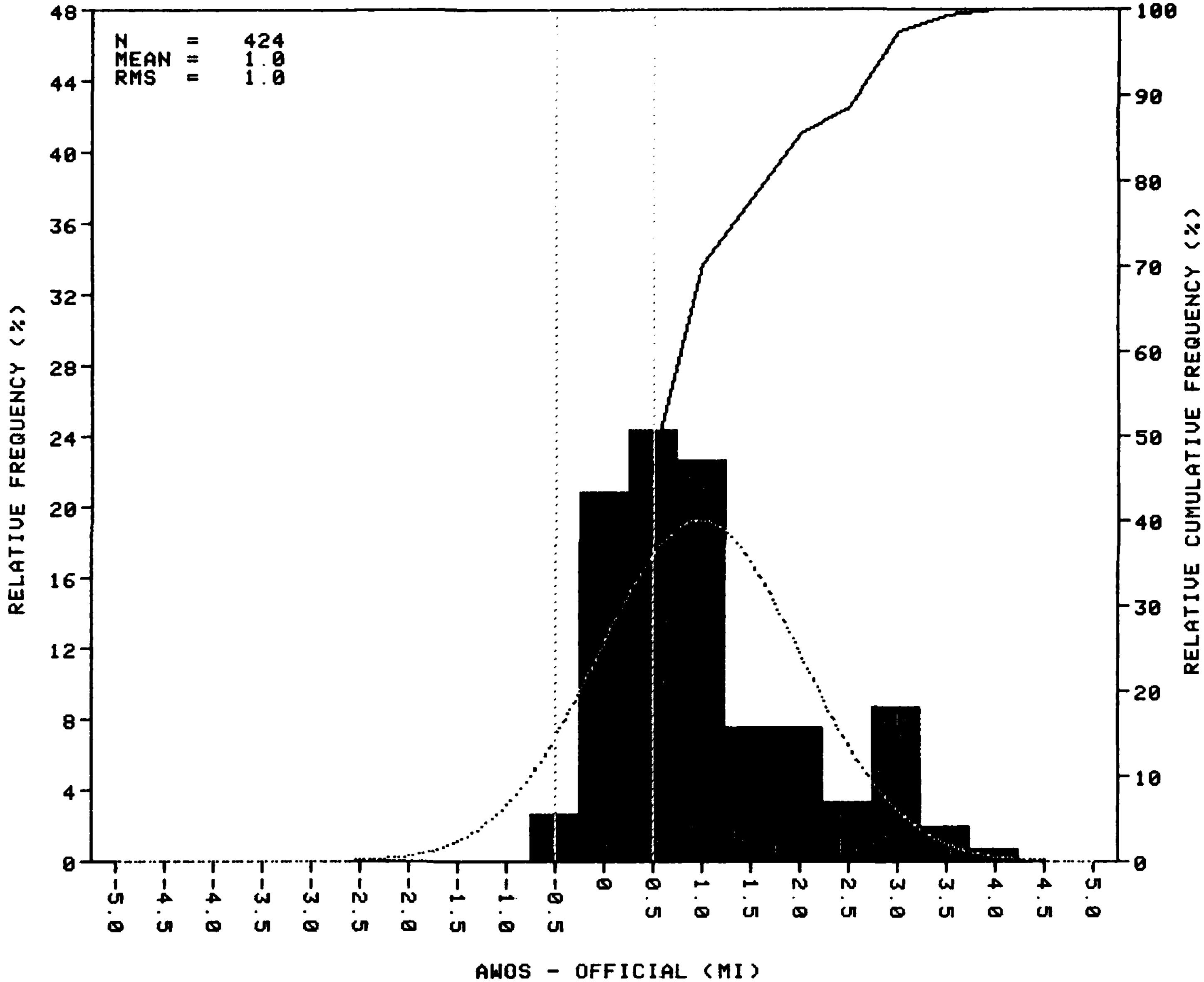

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FIGURE 18. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS 2 MILES OR LESS (SHEET 2 of 2)

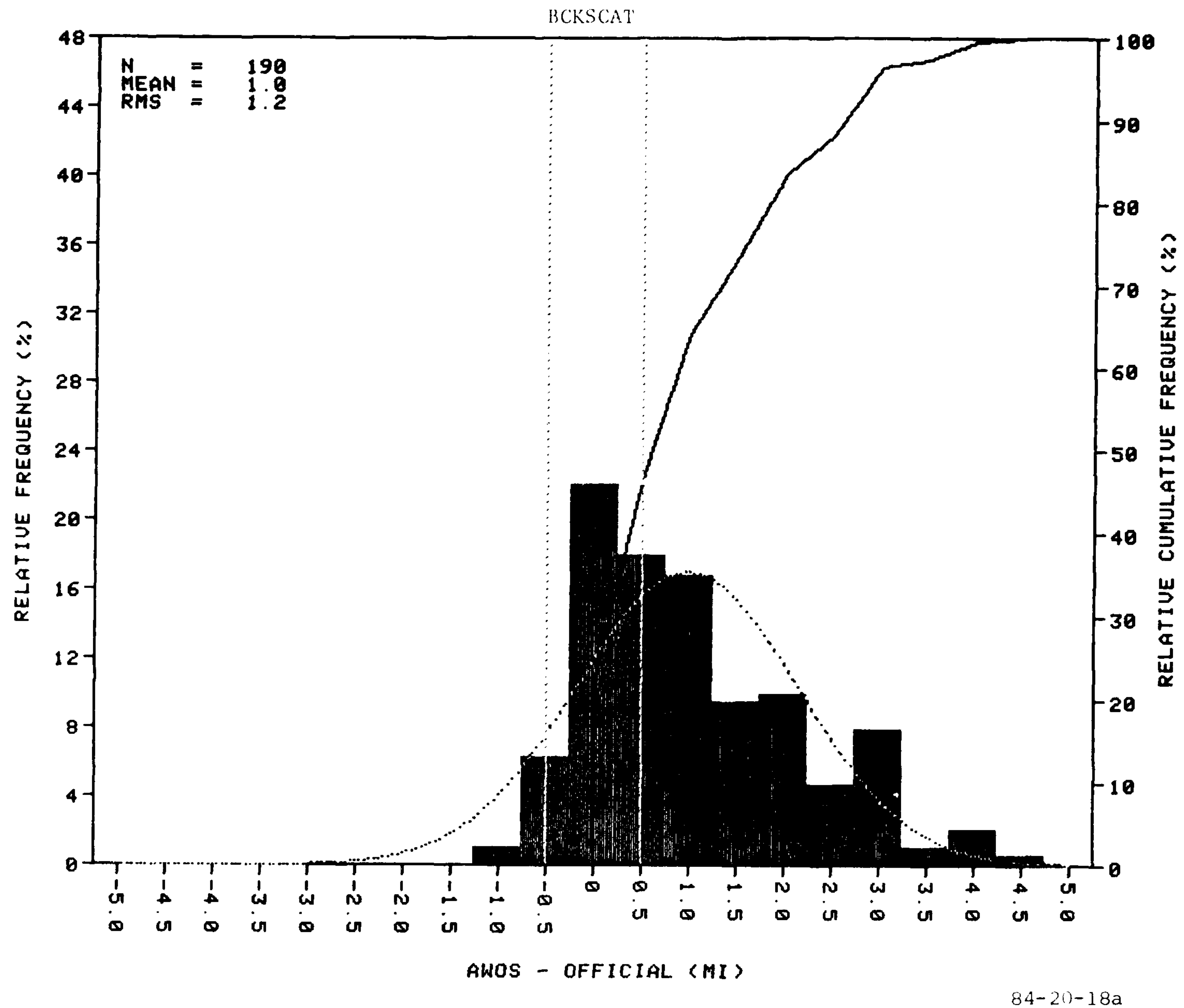

FIGURE 18. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS 2 MILES OR LESS (SHEET 1 OF 2)

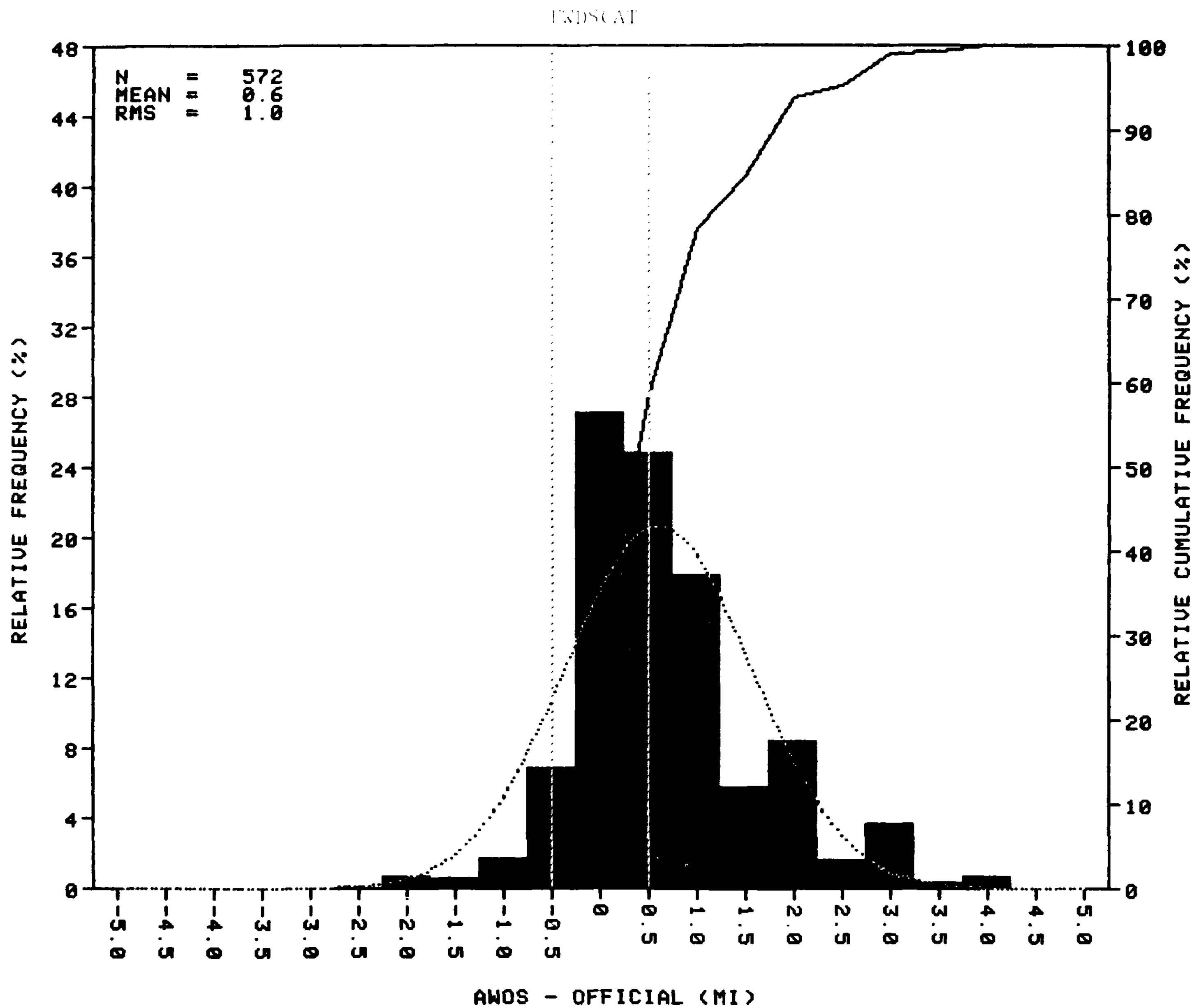

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FIGURE 17. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS 2 MILES OR LESS (SHEET 2 OF 2)

T1000

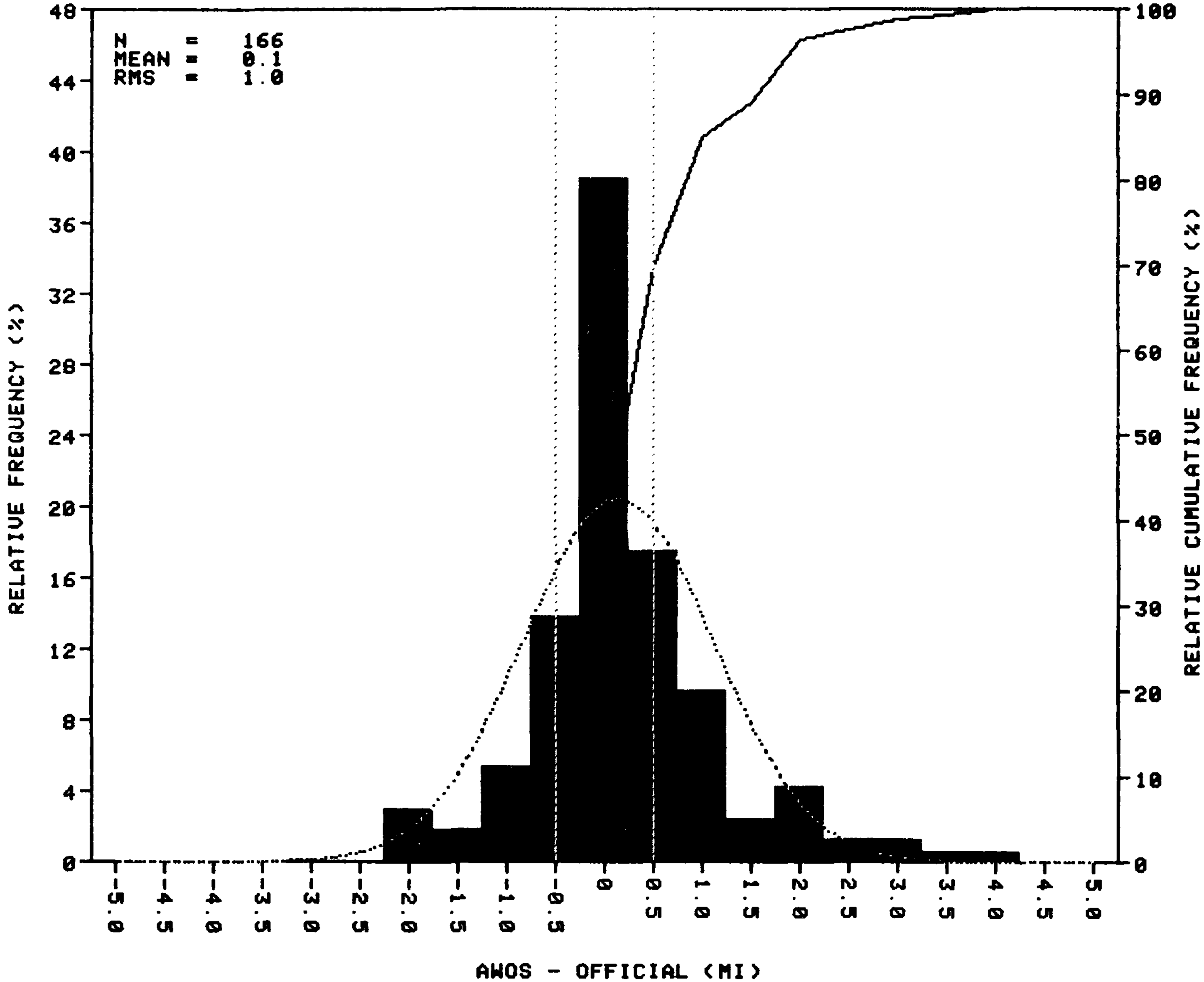

FIGURE 17. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS 2 MILES OR LESS (SHEET 1 OF 2)

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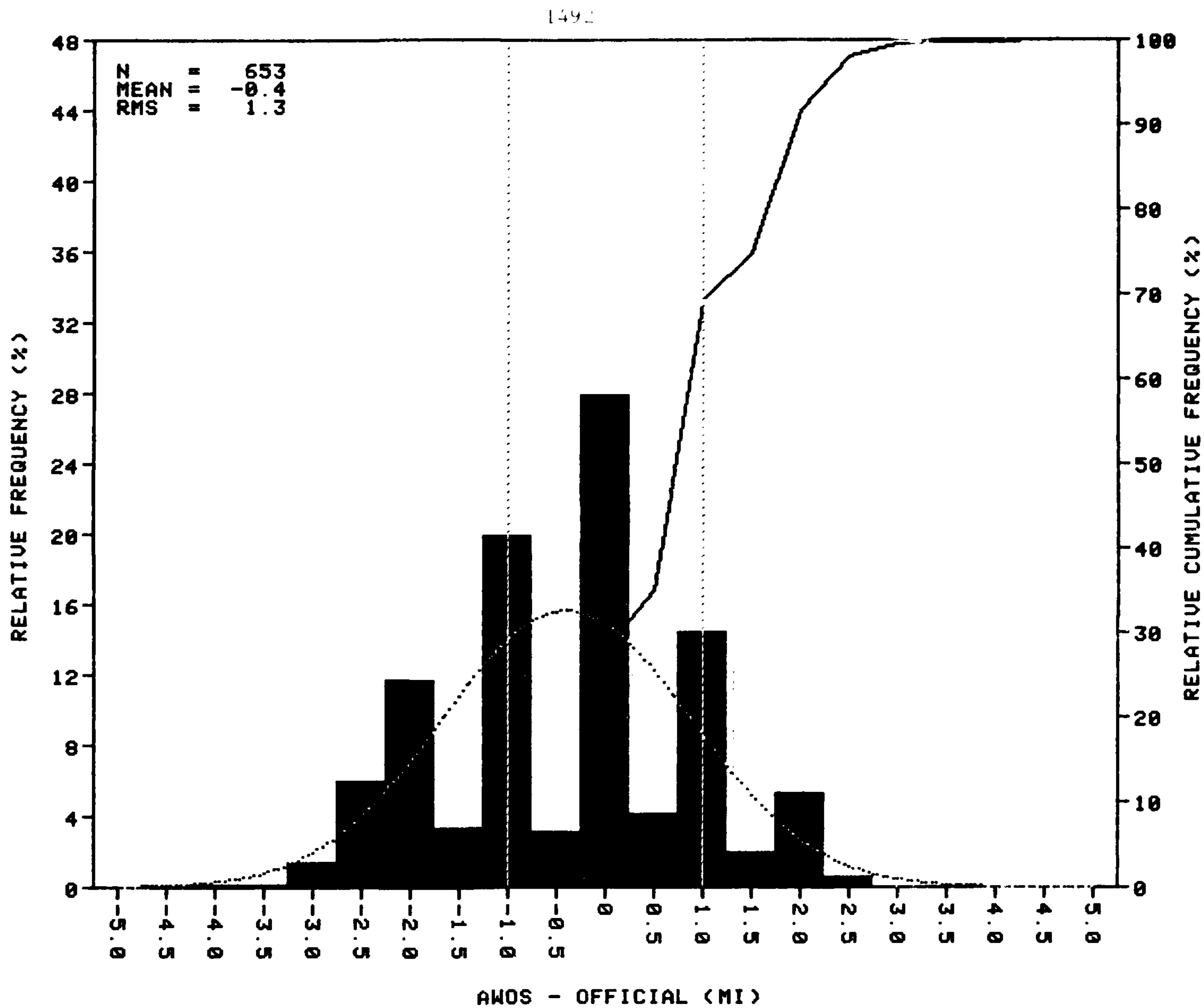

FIGURE 16. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS GREATER THAN 2 MILES (SHEET 2 OF 2)

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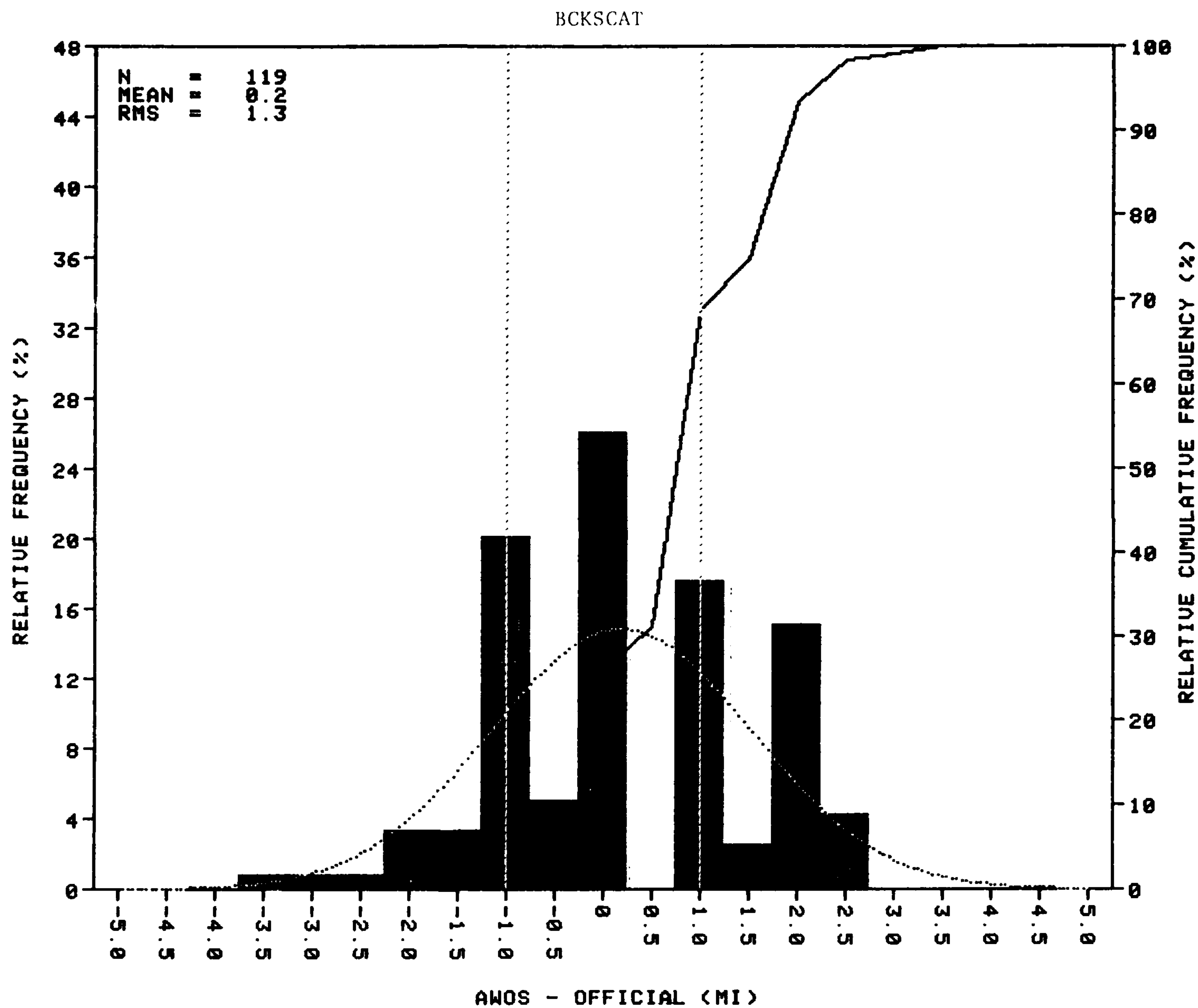

FIGURE 16. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS GREATER THAN 2 MILES (SHEET 1 OF 2)

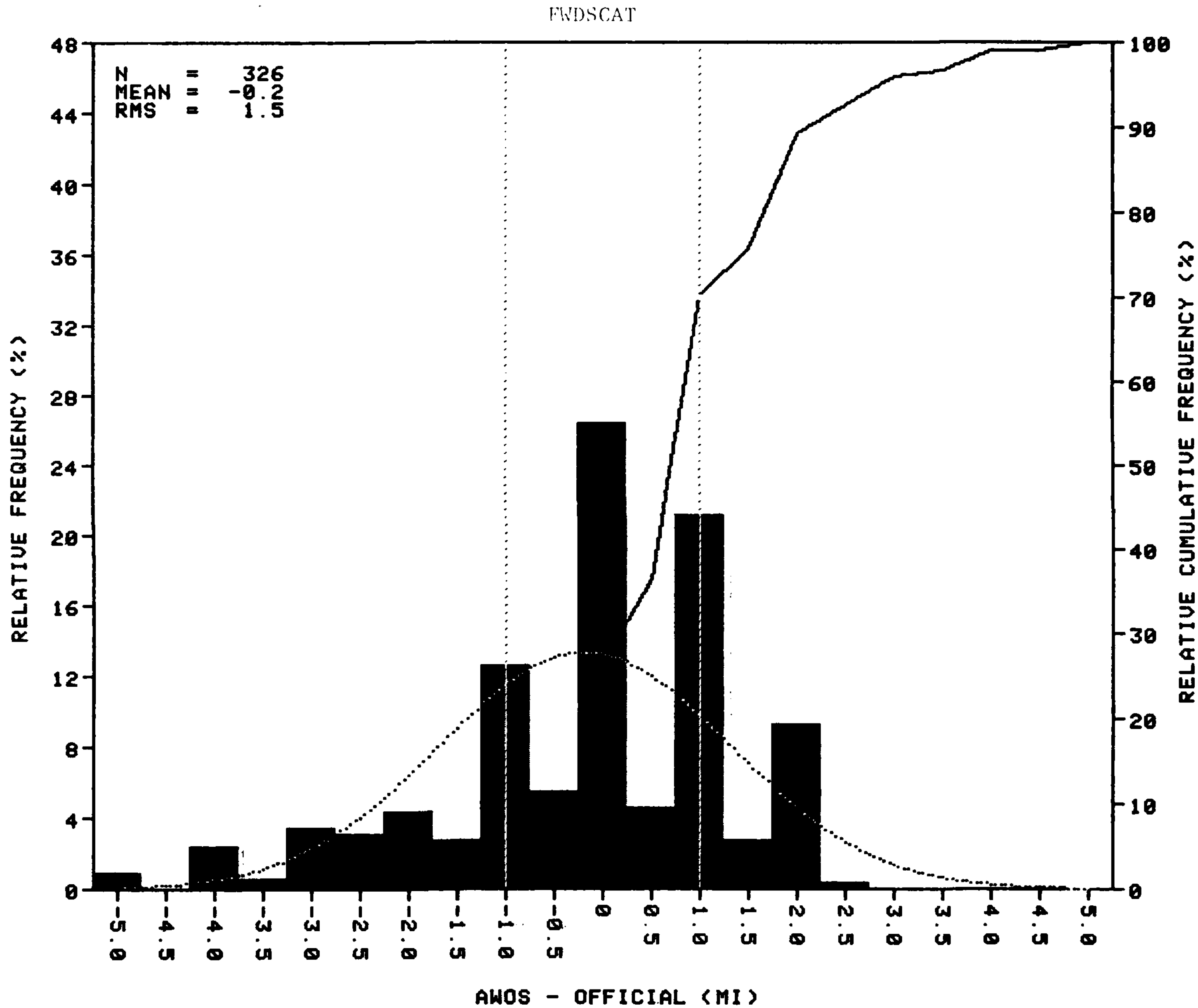

FIGURE 15. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS GREATER THAN 2 MILES (SHEET 2 OF 2)

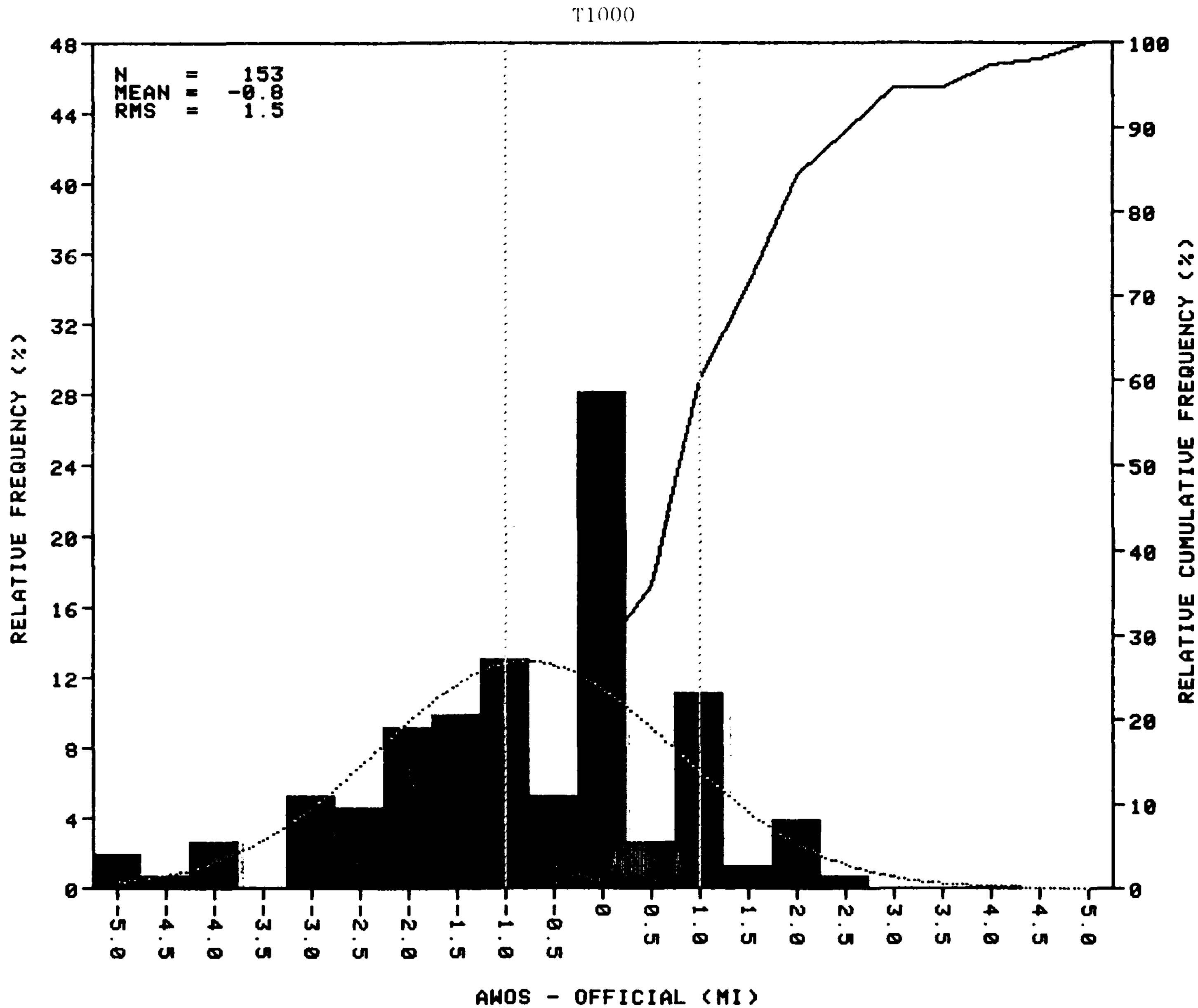

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FIGURE 15. VISIBILITY DIFFERENCE HISTOGRAMS FOR SENSORS WHEN OFFICIAL VISIBILITY IS GREATER THAN 2 MILES (SHEET 1 OF 2)

TABLE 28. VISIBILITY

Case	Sensor	N	r	$\bar{d}$	s	rms	RI
Overall	AWOS	2603	0.62	0.2	1.3	1.3	60
	T(1000)	319	0.58	-0.3	1.3	1.4	62
	FWDSCAT	898	0.65	0.3	1.2	1.3	61
	BCKSCAT	309	0.61	0.7	1.3	1.5	54
	T(492)	1077	0.61	0.1	1.3	1.4	60
Official Visibility >2 mi	AWOS	1245	0.16	-0.3	1.3	1.4	67
	T(1000)	153	0.18	-0.8	1.5	1.7	57
	FWDSCAT	326	0.17	-0.2	1.4	1.5	68
	BCKSCAT	119	0.08	0.2	1.3	1.3	69
	T(492)	647	0.16	-0.4	1.2	1.3	68
Official Visibility ≤2 mi	AWOS	1347	0.66	0.7	1.0	1.3	53
	T(1000)	166	0.60	0.1	1.0	1.0	65
	FWDSCAT	572	0.67	0.6	0.9	1.1	57
	BCKSCAT	190	0.59	1.0	1.2	1.5	45
	T(492)	419	0.70	1.0	1.0	1.4	46
Precipitation	AWOS	1286	0.62	0.4	1.2	1.3	59
	T(1000)	173	0.55	-0.2	1.2	1.2	62
	FWDSCAT	654	0.64	0.4	1.1	1.3	58
	BCKSCAT	182	0.61	0.7	1.2	1.4	62
	T(492)	277	0.64	0.6	1.1	1.3	57
Fog	AWOS	1564	0.64	0.2	1.2	1.3	63
	T(1000)	229	0.63	-0.2	1.2	1.3	66
	FWDSCAT	464	0.64	0.2	1.2	1.3	67
	BCKSCAT	196	0.55	0.7	1.4	1.5	51
	T(492)	675	0.66	0.3	1.2	1.2	63

TABLE 27. VISIBILITY OCCURRENCE

Case	Sensor	N_c	N	Distribution in Percent: AWOS >5 Official <5	Distribution in Percent: Joint Occurrence ≤5	Distribution in Percent: AWOS ≤5 Official >5
Overall	AWOS	15159	7225	15	36	49
	T(1000)	1042	857	5	37	58
	FWDSCAT	5501	1619	34	56	10
	BCKSCAT	2688	977	10	32	59
	T(492)	5928	3772	11	29	61
No Precipitation or Fog	AWOS		3540	8	7	86
	T(1000)		506	2	7	91
	FWDSCAT		325	57	7	36
	BCKSCAT		513	1	1	99
	T(492)		2196	3	8	89
Precipitation	AWOS		1776	18	72	10
	T(1000)		226	9	77	15
	FWDSCAT		369	20	75	5
	BCKSCAT		278	14	66	21
	T(492)		403	20	69	11
Fog	AWOS		2214	25	71	4
	T(1000)		255	8	90	2
	FWDSCAT		730	35	64	1
	BCKSCAT		241	15	81	4
	T(492)		988	24	69	7

frequency of occurrence distribution based on this 5-mile cutoff value. Detailed results by AWOS site, sensor, and case study are presented in table D-5 of appendix D. The results summarized by sensor and four case studies are given in table 27. This table shows the number of overall joint occurrences of visibility greater than 5 miles as N_C, and the visibility frequency distribution given in percent with respect to the remaining sample N.

Overall, approximately 68 percent of the 22,384 pairs of visibility observations were joint occurrences of visibility greater than 5 miles. The joint occurrence of AWOS and official visibility less than 5 miles during precipitation or fog conditions is about 72 percent. In general, the FWDSCAT devices significantly overestimate visibility more frequently than the other sensors. Based on the joint frequency of visibility less than or equal to 5 miles, the T(1000) performed better than the other sensors during conditions of precipitation and/or fog. This sensor performed particularly well in fog with 90 percent joint occurrences, while the FWDSCAT sensors showed the lowest performance in fog at 64 percent. During conditions of precipitation or fog when the official visibility is less than 5 miles, the FWDSCAT sensors reported visibility greater than 5 miles about 19 percent more often than the T(1000). In fog with official visibilities less than 5 miles, the frequency at which the T(1000) and FWDSCAT sensors falsely reported visibilities greater than 5 miles was 8 and 35 percent, respectively.

(3) Visibility Differences. Joint occurrences of visibility less than or equal to 5 miles were next examined for discrete visibility differences between AWOS and official. This was carried out for each site, sensor, and case study using the data reduction methods outlined previously. The results of the analysis are presented in table 28. Overall T(1000) and FWDSCAT relative and cumulative frequency histograms for visibility differences when the official visibility is greater than 2 miles is given in figure 15. Overall BCKSCAT and T(492) histograms for the same situation is given in figure 16. Overall histograms of T(1000) and FWDSCAT sensors when the official visibility is less than or equal to 2 miles is presented in figure 17. Histograms for BCKSCAT and T(492) are provided in figure 18.

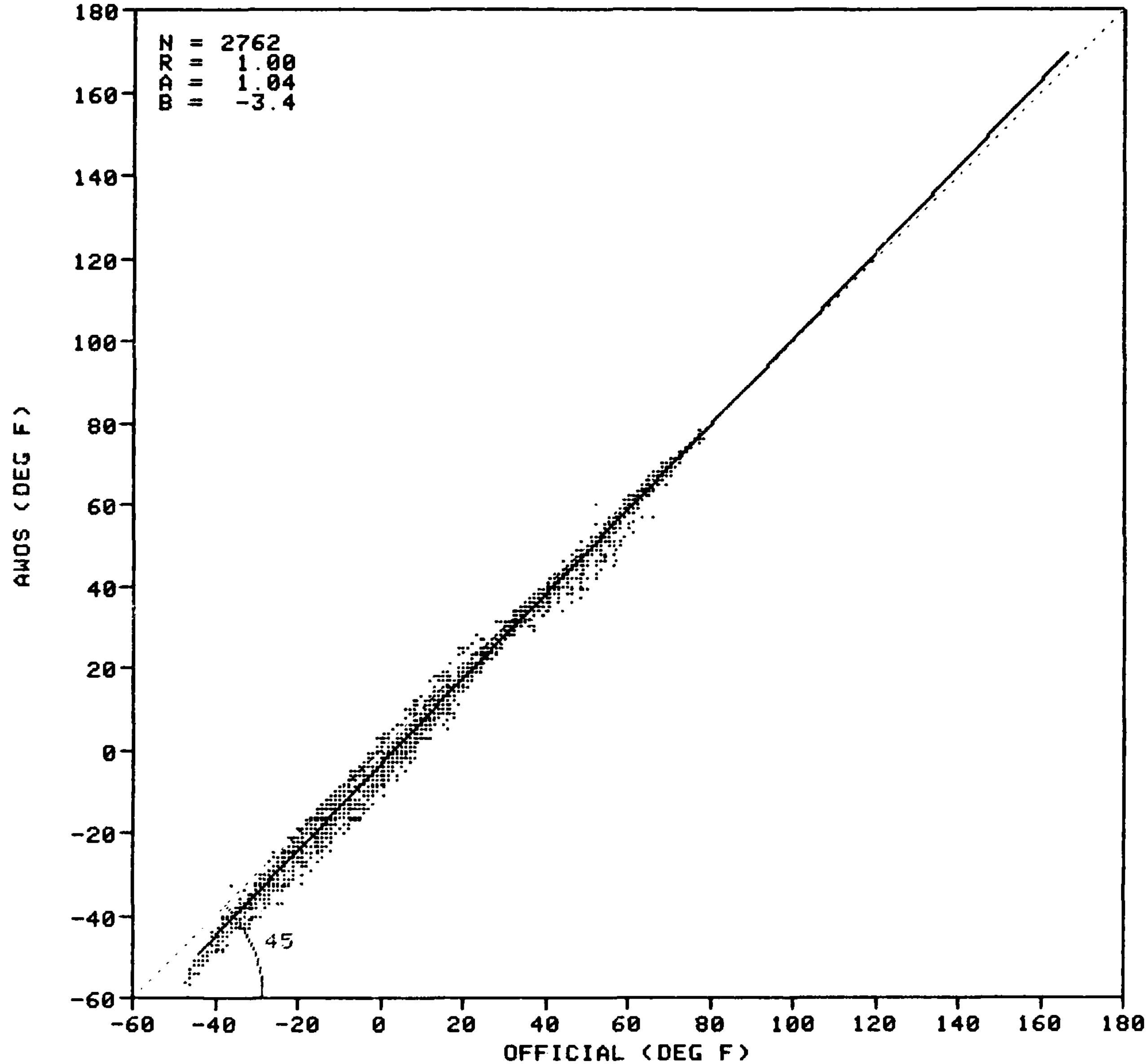
The results show a generally close agreement between the different sensors and case studies. Overall, AWOS had an rms value of 1.3 miles and reliability index of 60 percent. Overall performance is a few percent less when the official observer reports a precipitation occurrence or a visibility less than 2 miles.

Individual sensor performance is discernible when the results are examined separately by case study. The T(1000) and FWDSCAT sensors are significantly better performers when fog conditions or official visibilities less than or equal to 2 miles prevail. During precipitation events, the T(1000) and BCKSCAT sensors perform about 5 percent better than the other two sensors. The only case in which the T(1000) displays marginal performance with respect to the other sensors is when the observed official visibility is greater than 2 miles. Most of this error is not a result of the variance but attributed to a large bias value of about -0.8 miles. In fact, the T(1000) generally was on the conservative side by slightly underestimating visibilities while the other sensors showed positive bias values indicating visibility overestimation.

TABLE 26. VISIBILITY SENSOR SETUP

		Official Observation	
Site	AWOS Sensor Type	Height Above Ground (ft)	Distance to AWOS (ft)
CMX	Foward Scatter	0	3300
DBQ	Transmissometer (1000 ft)	0 (38)	1320
DCA	Foward Scatter	49	2640
HUM	Foward Scatter	47	3000
PWT	Transmissometer (1000 ft)	0	1980
SAF	Transmissometer (1000 ft)	47	5280
VDZ	Foward Scatter	0	1980
EEN	Back Scatter	0 (72)	6000
GAL	Back Scatter	27	3960
HOU	Transmissometer (492 ft)	0	2000
MIE	Transmissometer (492 ft)	65	1320
PSP	Transmissometer (492 ft)	50	1320
SBP	Transmissometer (492 ft)	13	990

Scattergram



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GALENA TEMPERATURE DIFFERENCE (SHEET 2 OF 2)

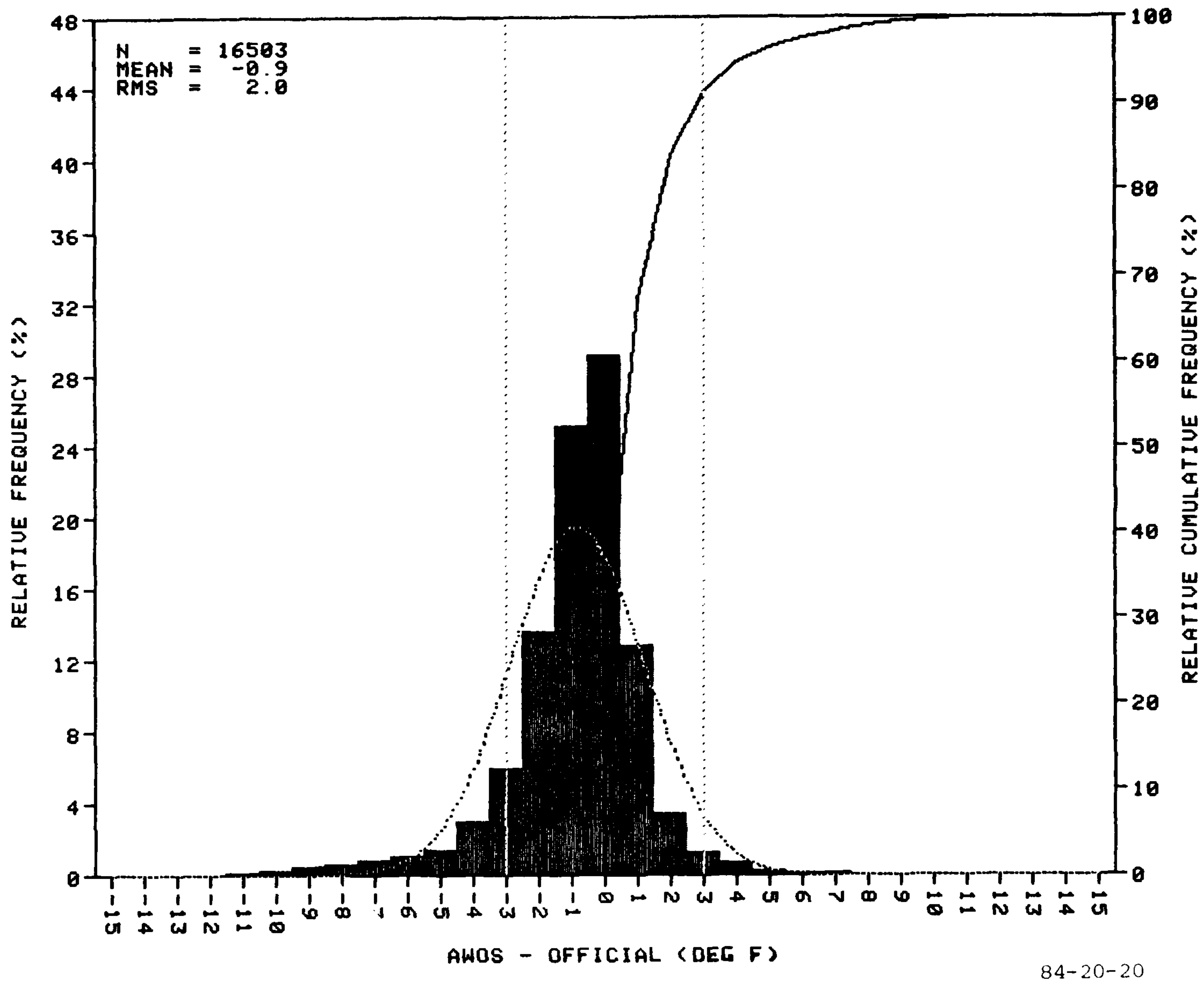

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FIGURE 20. OVERALL AWOS TEMPERATURE DIFFERENCE HISTOGRAM

According to the reliability index, 91 percent of the 16,503 pairs of AWOS and official temperatures differed by no more than ±3 °F. Artais temperature sensors (RI = 96 percent) were in agreement with official temperature, 9 percent more often than WeatherMeasure sensors were. Based on the rms error sensor function requirement of 3 °F, AWOS temperature performance is accepted as good with an rms value of 2.0 °F. With the exception of GAL, AWOS temperature sensor performance at all individual sites was also acceptable. GAL temperatures had the largest bias and rms error of -2.9 °F and 4.1 °F, respectively. In addition, the difference between AWOS and official increased as the temperature decreased below zero.

(5) Dew Point. Results of the dew-point temperature are given in table D-7 and summarized in table 30. An overall AWOS dew point temperature difference histogram is presented in figure 21. Official observations of dew point were not taken at HUM, EEN, MIE, PSP, and SBP. Overall AWOS dew point performance was about 11 percent less than the corresponding temperature performance.

TABLE 30. DEW POINT TEMPERATURE

System	N	r	$\bar{d}$	s	rms	RI
AWOS	13763	0.99	-1.7	2.6	3.4	80
Artais	7003	0.98	-2.9	2.9	4.5	65
WxMeasure	6760	0.99	-0.4	2.2	2.3	96

Based on the 13,763 paired samples, overall AWOS dew point performance was acceptable with an rms error of 3.4 °F and a reliability index of 80 percent. WeatherMeasure performance was 31 percent better than the marginal performance of the Artais dew point sensors. Much of the Artais difference was attributed to a large bias error of -2.9 °F.

WeatherMeasure sites at HOU and GAL displayed the best overall performance while the Artais sites at CMX, DCA, and VDZ showed considerably lower performance, mainly as a result of large negative bias values. These bias values alone almost exceed the sensor rms error functional requirements.

The AWOS site at DCA exhibited the lowest reliability with a corresponding rms error and reliability index of 5.3 °F and 48 percent. A time-series plot and scattergram for DCA dew point temperature differences are given in figures 22a and 22b, respectively. These figures basically show that the dew point temperature is increasingly underestimated by AWOS as the temperature increases. This behavioral trend is not typical of the other sites.

Three possible explanations of this generally erratic behavior in dew point is: (a) poor siting and exposure of the official (or AWOS) dew point sensor; (b) AWOS or official sensor out of calibration; and/or (c) depleted moisture reservoir in the AWOS or official dew cells.

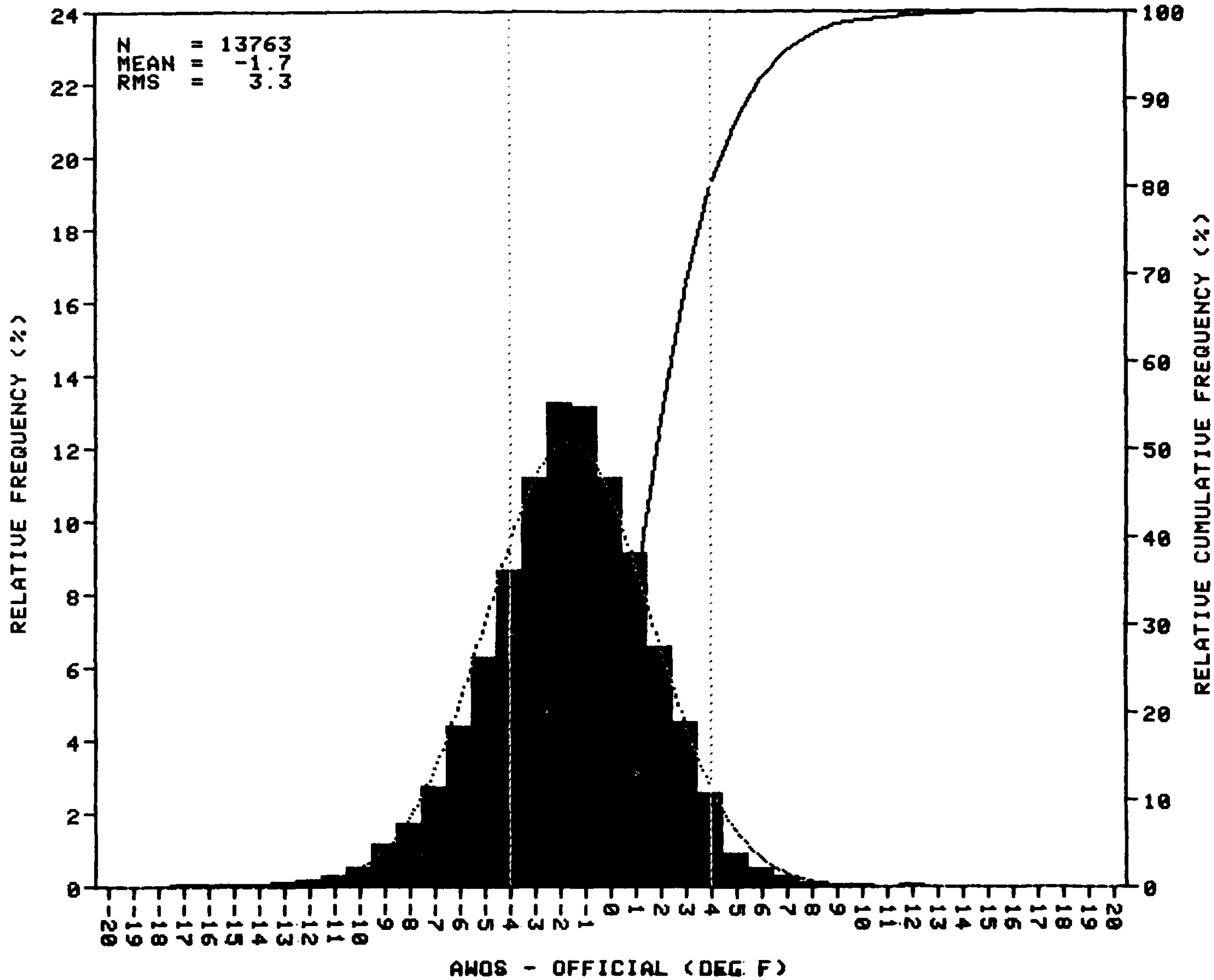

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FIGURE 21. OVERALL AWOS DEW POINT TEMPERATURE DIFFERENCE HISTOGRAM

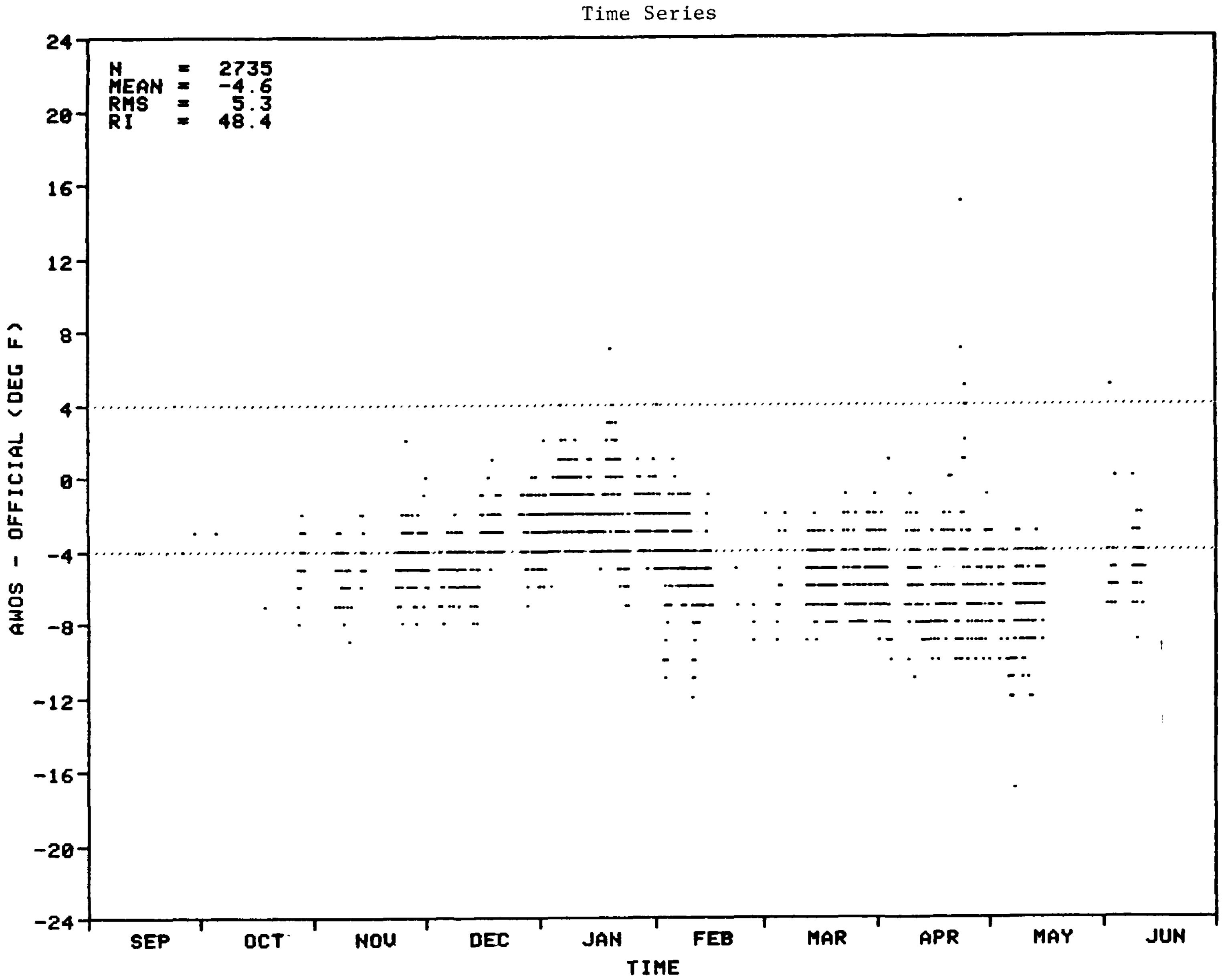

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FIGURE 22. WASHINGTON, D.C., DEW POINT TEMPERATURE DIFFERENCE (SHEET 1 OF 2)

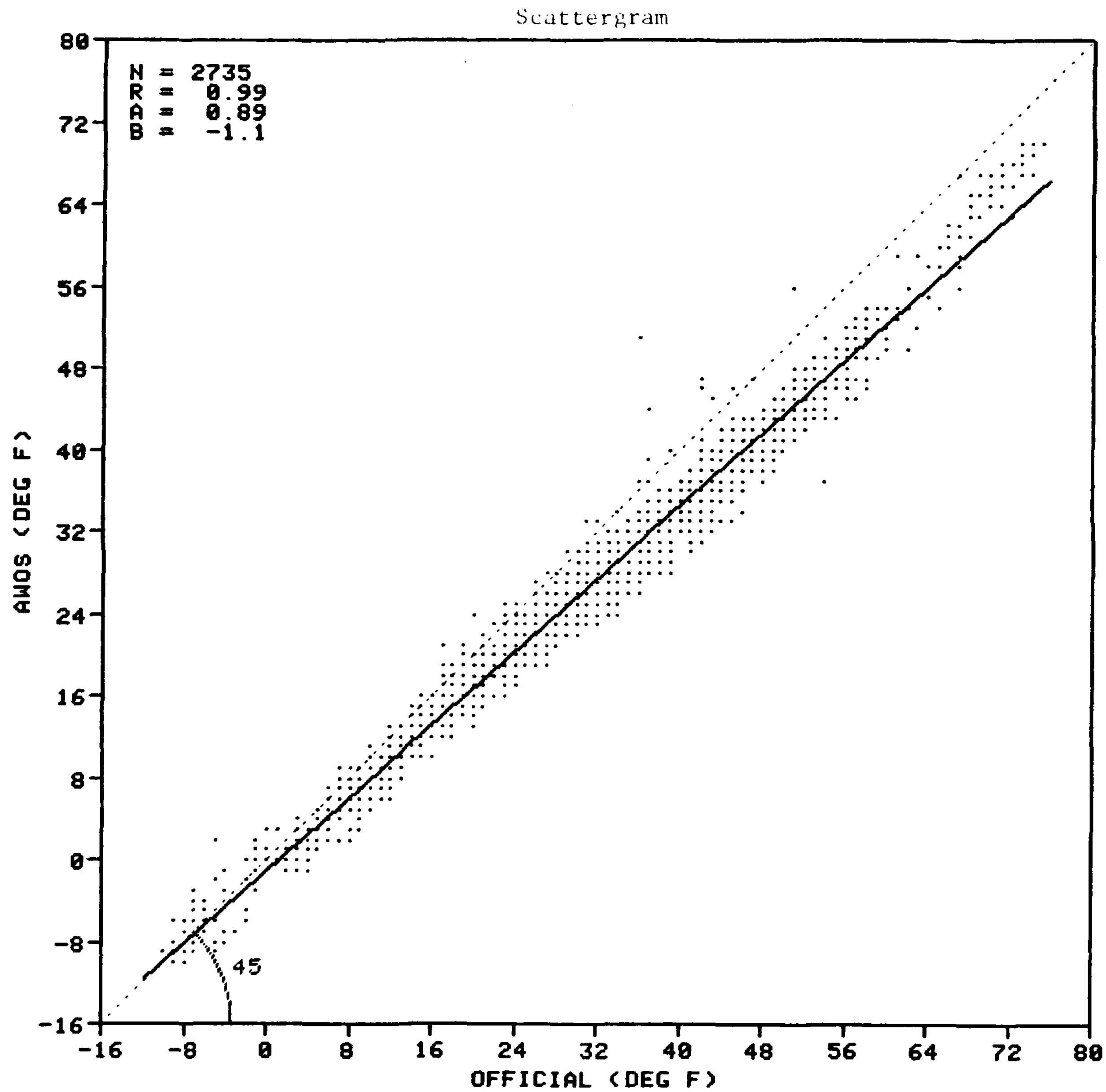


FIGURE 22. WASHINGTON, D.C., DEW POINT TEMPERATURE DIFFERENCE (SHEET 2 OF 2)

(6) Altimeter Setting. Results of altimeter setting for each AWOS site are given in table D-9 in appendix D. These results are summarized by AWOS type in table 31. An overall histogram of altimeter setting differences for AWOS is given in figure 23.

TABLE 31. ALTIMETER SETTING

System	N	r	$\bar{d}$	s	rms	RI
AWOS	21102	0.99	-0.003	0.011	0.015	99
Artais	8857	0.98	-0.008	0.010	0.014	100
WxMeasure	12245	0.99	0.001	0.013	0.015	99

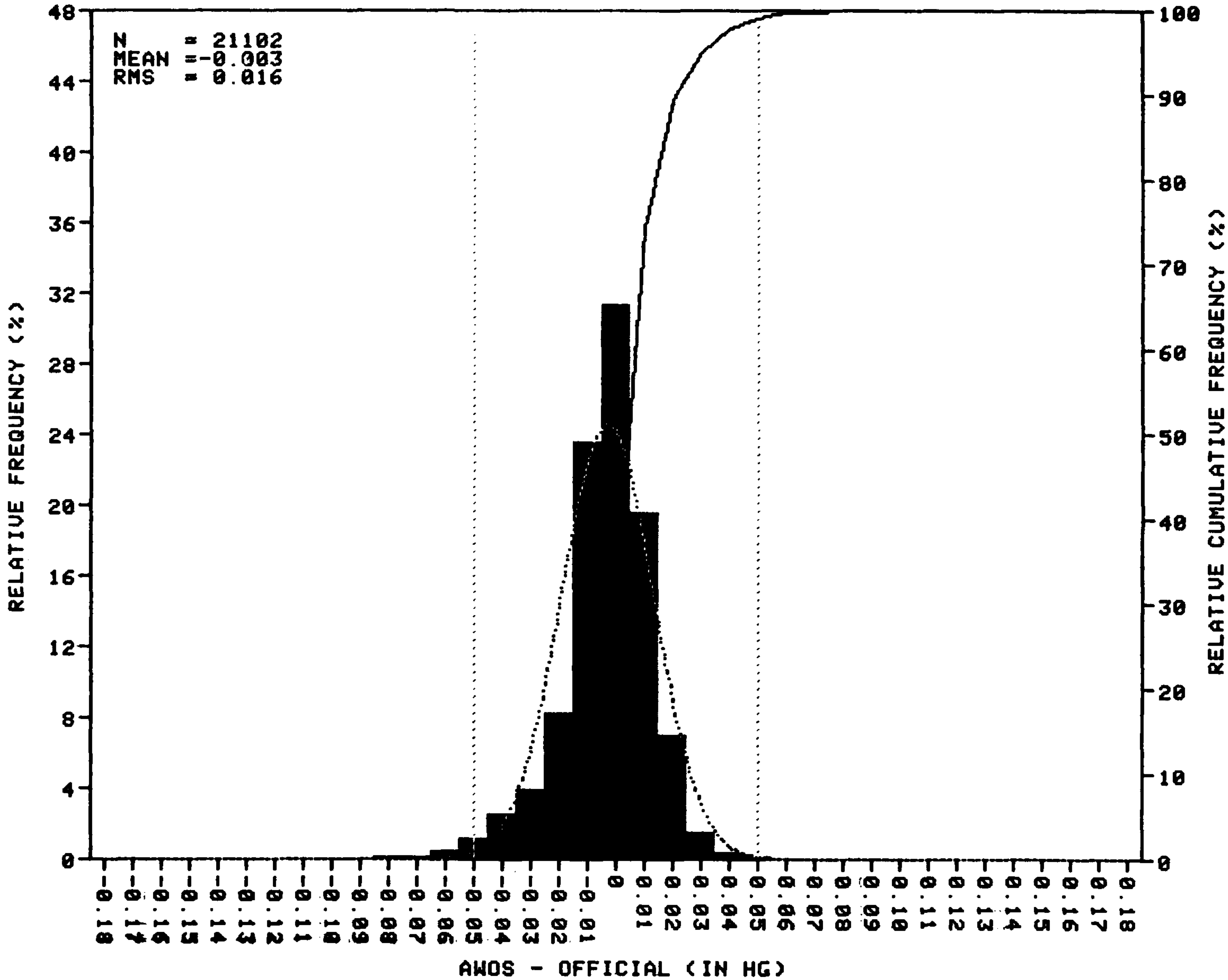
All the statistics show that AWOS altimeter setting is exceptionally reliable. The rms values of 0.014 and 0.015 in Hg are 70 percent within the prescribed rms error sensor functional requirement of 0.05 in Hg. The largest disagreement between AWOS and official was at EEN and HUM. Calibration problems of the official barometric pressure sensor at EEN were noted early in the experiment. Despite their relatively weak performance when compared with other sites, the rms error of EEN and HUM altimeter settings is still acceptable since they were both within the 0.05 in Hg tolerance.

The remarkably good performance of the AWOS altimeter setting is not surprising for three reasons: (a) the AWOS processor continuously samples and compares two barometric pressure sensors; (b) AWOS and official pressure sensors are not sensitive to siting and exposure criteria as are other meteorological sensors; and (c) AWOS and official pressure sensors do not require periodic inspection and routine maintenance. Based on all of the results and the prescribed sensor function requirements, altimeter setting is clearly the most reliable parameter reported by AWOS.

(7) Wind Direction.

(a) General. Table 32 provides background information on the AWOS and official wind sensor setup. This table gives the following information for each site: (1) magnetic variation or compass declination, (2) AWOS reported wind direction according to true or magnetic north, (3) official wind sensor height above ground, (4) distance of official wind sensor location to AWOS, and (5) siting and exposure of official wind sensor.

The AWOS wind sensors are situated at the standard 10-meter height (33 feet above ground) while the height of the official wind sensors varied from 10 to 76 feet above ground, depending on the site. Only PWT and VDZ had official wind sensors located at the standard height. The AWOS wind sensor at GAL was mounted 20 feet above ground so that the sensor would not extend into the glide slope clear zone. All official wind directions are reported with respect to true north in accordance with FMH-1 procedures. Data from those AWOS wind sensors which measured magnetic winds were converted to true north in the data processing by adding or subtracting the site magnetic variation. The procedure used to convert from magnetic to true winds is outlined in appendix D.



84-20-23

FIGURE 23. OVERALL AWOS ALTIMETER SETTING DIFFERENCE HISTOGRAM

TABLE 32. WIND SENSOR SETUP

Site	Magnetic Variation (deg)	AWOS Wind	Official Sensor Height (ft)	Official Sensor Distance to AWOS (ft)	Exposure
CMX	0	True	70	3300	Partially Obstructed
DBQ	4 East	True	20	1320	Centerfield
DCA	7 West	Mag	25	900	Centerfield
HUM	6 East	True	14	4000	Centerfield
PWT	21 East	True	33	2000	Unobstructed
SAF	12 East	True	10	4250	Unobstructed
VDZ	28 East	True	33	2640	Partially Obstructed
EEN	14 West	Mag	47	6000	Wind Sock Sometimes
GAL	26 East	True	12	150	Partially Obstructed
HOU	8 East	Mag	20	3000	Centerfield
MIE	2 West	Mag	76	1320	Unobstructed
PSP	14 East	True	18	2640	Unobstructed

The airfield location of the official wind sensors varied from one site to the next. Partially obstructed official wind sensors were typically located near, or on top of, buildings. The influence of these physical obstructions on the official wind sensors is more prevalent for certain wind directions than for others. AWOS wind sensors are usually more representative of runway wind conditions since these sensors are typically well exposed at runway touchdown locations.

(b) Results. Results for wind direction are given in table D-10 for each AWOS site. A summary of these results by system are given in table 33. An overall wind direction difference histogram for AWOS is given in figure 24. Wind direction data were compared only for moderate to strong wind cases, i.e., AWOS wind speeds greater than 5 knots.

TABLE 33. WIND DIRECTION

System	N	r	$\bar{d}$	s	rms	RI
AWOS	11686	0.98	7	19	21	91
Artais	6110	0.98	6	17	20	93
WxMeasure	5576	0.98	8	21	23	90

The rms error sensor functional requirement for wind direction is 35°. Based on this criterion, overall AWOS, Artais, and WeatherMeasure performance for wind direction is acceptable. About 91 percent of AWOS minus official wind direction differences were within ±35°.

The best wind direction performance was exhibited at DBQ, DCA, and HOU. Their rms error values ranged between 15° and 17°. Individual sites at PWT, SAF, VDZ, EEN, and PSP displayed unacceptable performance with rms errors greater than the 35° tolerance. Much of the observed error is attributed to large bias values, particularly for PWT. Wind sensor setup may partially explain some of this large error. First, PWT had the largest bias magnitude (-38°), but relatively small variance. PWT personnel reported that the AWOS wind sensor orientation was with respect to true north, with no sheltering of either the AWOS or official sensors. Orientation of the AWOS wind sensor at PWT may be questionable since a postulation of AWOS reporting magnetic winds would significantly reduce the bias error to -17°. In general, wind sensor misalignment directly affects the bias value. This, in turn, adds to the rms error and decreases the reliability index. Some of the error at SAF may be attributed to the low 10-foot height of the official wind sensor. The partially obstructed official wind sensor at VDZ probably contributed to the large standard deviation of 50°. Overall quality of official wind data from EEN is uncertain since a wind sock is sometimes used at this site. Finally, a large bias and standard deviation was observed for PSP. It was reported that the official wind sensor is often influenced by a local mountain flow while the AWOS sensor, located about 1/2 mile away, is not affected. Also, strong daytime differential surface heating is prevalent at PSP.

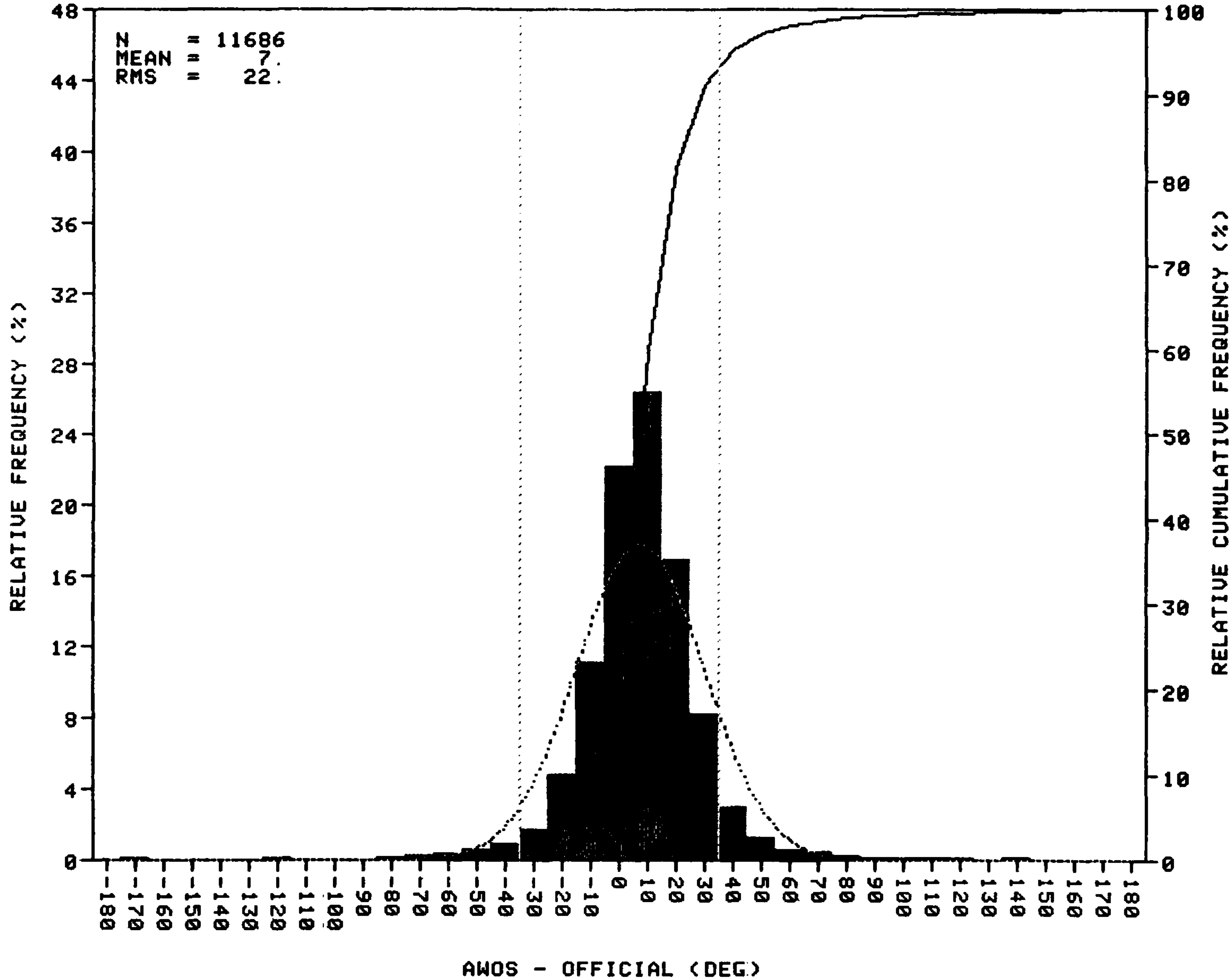


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FIGURE 24. OVERALL AWOS WIND DIRECTION DIFFERENCE HISTOGRAM

(8) Wind Speed. Wind speed comparisons between AWOS and official were carried out for moderate to strong wind cases, i.e., AWOS wind speed greater than 5 knots. Wind speed results by AWOS site are provided in table D-11 of appendix D. A summary of these results is given in table 34. An overall AWOS wind speed difference histogram is given in figure 25. As additional information, the wind sensor setup description previously described is outlined in table 32.

TABLE 34. WIND SPEED

System	N	r	$\bar{d}$	s	rms	RI
AWOS	11871	0.78	-0.7	2.6	2.9	93
Artais	6122	0.83	0.2	2.3	2.4	97
WxMeasure	5749	0.73	-1.6	2.8	3.4	88

Based on the rms error sensor functional requirement of 5 knots, every AWOS site exhibited acceptable performance. The overall rms error and reliability index for AWOS wind speed was 2.9 knots and 93 percent, respectively. Artais systems showed better overall performance than the WeatherMeasure systems. The cause of this difference is unaccountable due to the different official wind sensor configurations at each site.

Sites at DBQ and DCA displayed the most reliable wind speed performance with an average rms value of 2.1 and 2.2 knots, respectively. Marginally acceptable performance was found at MIE which had a bias and rms error of -3.7 and 4.8 knots, respectively. The unusually large negative bias is mostly attributed to the height of the official wind sensor. This sensor is about 76 feet above ground and situated only 7 feet above the roof of an ATC tower. The bias value of the wind speed difference (AWOS minus official) is negative and large in magnitude due to the higher location of the official wind sensor than the AWOS sensor. High winds and turbulence around the leading edge of the tower roof can also contribute to the observed error. Wind speed error for sites at PWT, SAF, VDZ, EE., and PSP was slightly more than for the other sites. This error is correlated with large wind direction errors found at the same sites. Consequently, the observed wind speed error can be attributed to the same sensor-siting factors discussed in the previous section.

(9) Wind Gust. The first phase of this analysis was to construct a frequency distribution based on the number of occurrences of AWOS and official reported wind gusts. This was conducted in order to check the overall sensitivity and responsiveness of the AWOS wind gust algorithm. In view of the unsteady nature of wind gusts, a time difference tolerance of 10 minutes (instead of 15 minutes) was used when pairs of AWOS and corresponding official observations were selected and compared.

The frequency distribution is given for each site in table D-12 and summarized in table 35. In general, AWOS reports wind gusts more frequently than the official observer indicating a highly sensitive AWOS wind gust algorithm. The converse was true for the AWOS sites in Alaska (VDZ and GAL). Specifically, AWOS reported wind gusts 34 percent more frequently than official observers.

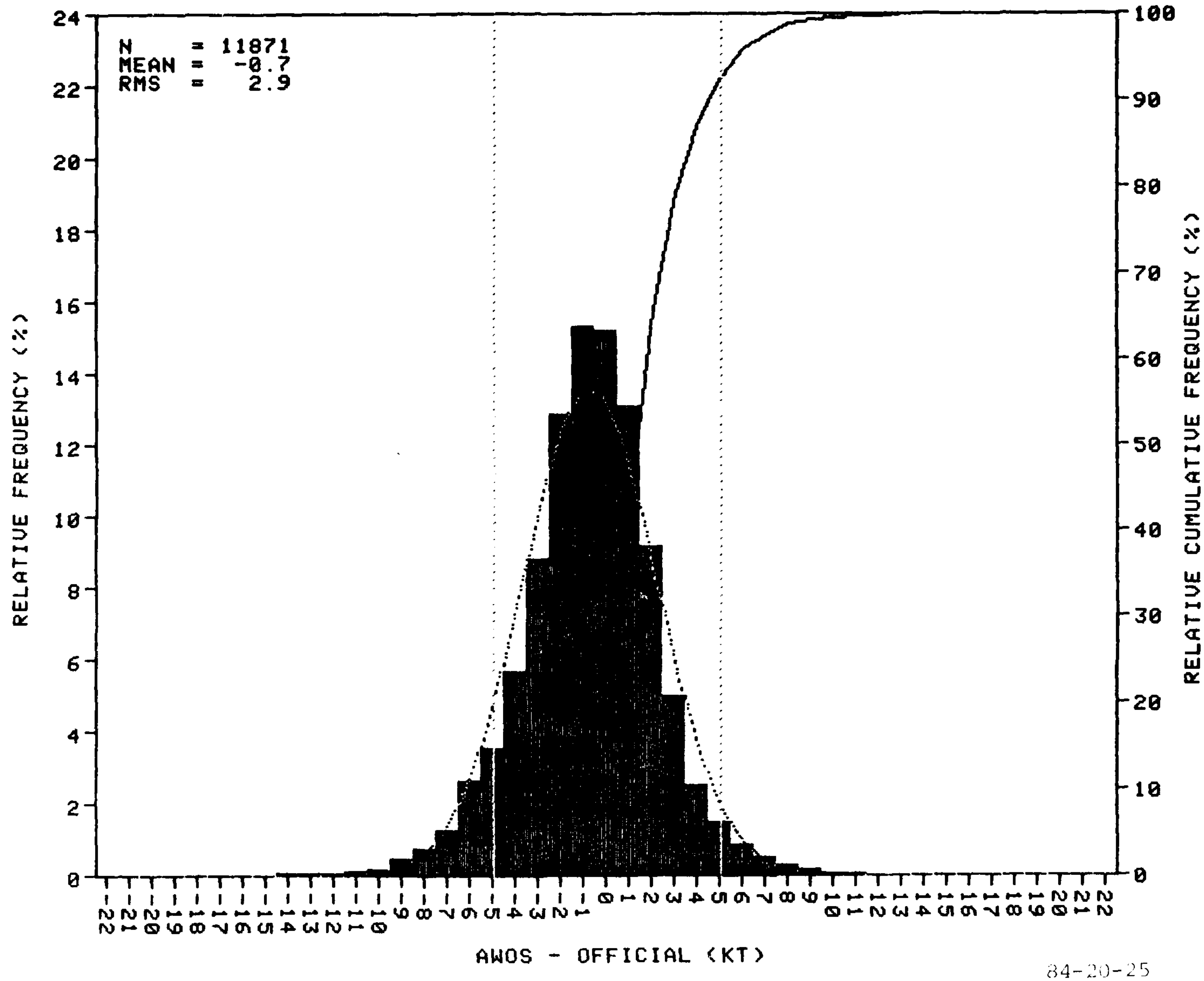

FIGURE 25. OVERALL AWOS WIND SPEED DIFFERENCE HISTOGRAM

About 15 percent of the time official observers reported gusts while AWOS did not. Due to the intrinsic characteristics of the AWOS gust algorithm, AWOS is generally more sensitive to wind gusts than human observers who subjectively recognize wind gusts from dial indicators and recorders.

TABLE 35. WIND GUST OCCURRENCE

			Distribution in Percent		
System	N	AWOS Official	No Yes	Yes Yes	Yes No
AWOS	2174		15	36	49
Artais	1376		18	42	40
WxMeasure	798		10	26	65

Next, joint occurrences of wind gusts were examined for their wind speed differences. The results are displayed for seven sites in table D-13 in appendix D. A summary of these results is given in table 36. An overall histogram for wind gust speed difference is given for AWOS in figure 26.

TABLE 36. WIND GUST SPEED

System	N	r	$\bar{d}$	s	rms	RI
AWOS	758	0.72	-0.1	3.6	3.6	88
Artais	565	0.76	-0.1	3.2	3.3	91
WxMeasure	193	0.60	0.0	4.7	4 7	80

Based on a rms error tolerance of 5 knots, overall AWOS wind gust performance was acceptable with an rms error of 3.6 knots. According to the reliability index, Artais sites agreed better with the official observers about 11 percent more than WeatherMeasure sites. The best performance was exhibited at DBQ with an rms error of 2.9 knots.

The highest reported AWOS wind gust was 69 knots at CMX on December 23. At that time the official observer had reported a wind gust of 30 knots 2 minutes earlier. The prevailing weather conditions were characterized by snow, blowing snow, near-zero visibility, high winds, and strong gusts. A time difference of at least 2 minutes, and the different sampling and averaging time of the AWOS algorithm and official observer, contributed to the observed wind gust speed difference of 39 knots.

(10) Precipitation Occurrence. Artais and WeatherMeasure Systems employ heated tipping-bucket rain gauges for the detection of precipitation occurrence (and amount). In addition, Artais uses a resistance-type Wong precipitation sensor for precipitation occurrence detection. The relative frequency distribution of precipitation occurrence for each AWOS site is provided in table D-14 and summarized in table 37.

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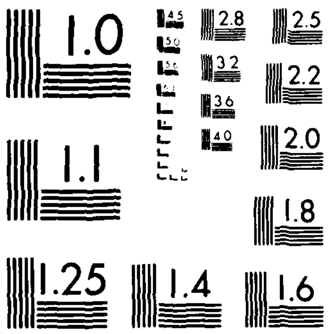


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

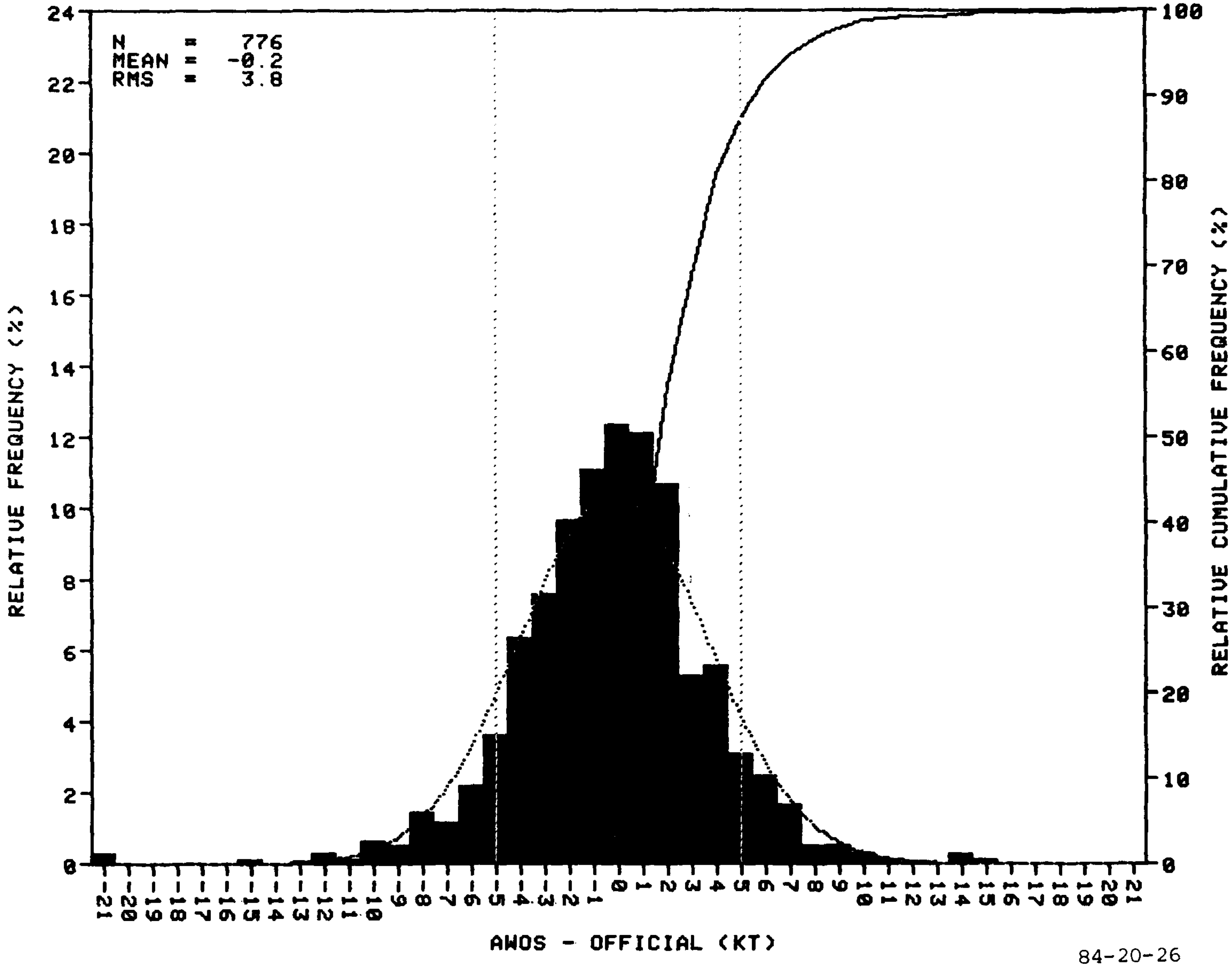


FIGURE 26. OVERALL AWOS WIND GUST SPEED DIFFERENCE HISTOGRAM

TABLE 37. PRECIPITATION OCCURRENCE

System	N	AWOS Official	No Yes	Yes Yes	Yes No
			Distribution in Percent		
AWOS	2687		62	27	12
Artais	1571		67	25	8
WxMeasure	1116		54	29	17

The results show that AWOS significantly lacks in the detection capabilities of precipitation occurrences. Overall, about 62 percent of the time AWOS does not detect the presence of precipitation. Only 27 percent of the time AWOS and official observers jointly report precipitation occurrences. The best detection capabilities were displayed by sites at EEN and DCA. WeatherMeasure sensors were generally better performers than Artais sensors.

The joint detection of precipitation occurrence by official precipitation type is given for each site in table D-15 and summarized in table 38. These tables give the percent of times AWOS detects a precipitation occurrence according to the type of prevalent official precipitation.

TABLE 38. PRECIPITATION OCCURRENCE BY TYPE

Precipitation Type	System	Official Occurrences	Percent Detected by AWOS
Rain	AWOS	1173	49
	Artais	701	44
	WxMeasure	472	56
Snow	AWOS	1264	13
	Artais	797	12
	WxMeasure	467	16

The results show that AWOS detects rain 49 percent of the time, but detects snow as a precipitation occurrence only 13 percent of the time. The clearly unacceptable performance for the latter case is mostly attributed to inadequate heating elements in the rain gauges. By far, the best performance was exhibited at EEN. At this site, AWOS jointly detected precipitation 70 and 71 percent of the time for rain and snow, respectively. WeatherMeasure showed slightly better performance than Artais for rain and snow.

An interesting point depicted in the foregoing two tables is the generally better performance by WeatherMeasure than Artais. This is a surprising result in view of the fact that the Artais Systems employ an additional sensor which is designed specifically for precipitation occurrence detection.

CONCLUSIONS

Based on the results of the data analyzed during the 10-month Automated Weather Observing System (AWOS) demonstration period of September 1983 - June 1984, it is concluded that:

1. Pilots generally were favorable in their reaction to the AWOS concept, especially its availability and currency in the reporting of aviation weather parameters, and the performance of the system in which they accorded an above average rating of 3.64 on a scale of one to five.

2. Use of discrete very high frequency (VHF) and non-Doppler type omnidirectional range (VOR's) were considered the most favored means of access to AWOS. This was reflected in the 4.0 system rating by pilots.

3. Doppler VOR is inadequate as a means of access to AWOS. Pilots who used the Houston, Texas, Doppler VOR site accorded the AWOS a low system rating of 2.75. The principle difficulty is attributed to the 10 kilohertz (kHz) side-band modulation, typical of Doppler VOR.

4. Pilots experienced difficulties with the synthesized voice message as reflected in 44 percent of the unfavorable responses. This difficulty was predominant with WeatherMeasure which had 86 unfavorable comments in contrast to Artais which had 34 unfavorable comments. In the case of WeatherMeasure, this was attributed to the announcer who spoke with a monotone cadence which was without variation and pitch.

This difficulty is not considered serious as a very specific standard for voice quality exists in the AWOS production specification. Artais and WeatherMeasure were not required to comply with this standard.

5. The Artais System experienced 184 failures which were substantially greater than the 16 failures experienced with the WeatherMeasure System. This is considered to be principally due to system software design differences. As a direct consequence, the system mean-time-between-failure (MTBF) value for Artais was greater than 250 hours; whereas, the system MTBF value for WeatherMeasure was greater than 3,000 hours.

6. Performance of AWOS in detecting and reporting visibility, temperature, dew point, barometric pressure, wind direction, wind speed, and wind gust was acceptable. In each case, sensor functional requirements were surpassed.

7. Performance of AWOS in detecting and reporting precipitation was unacceptable. The poor performance, primarily with detection in freezing conditions, was attributable to inadequate heating elements.

8. Performance of AWOS in detecting and reporting cloud elements during precipitation was unacceptable. Performance in detecting and reporting the number of cloud layers, cloud coverage, and cloud height in the absence of precipitation was marginal to good.

RECOMMENDATIONS

Based on the conclusions it is recommended that:

1. Doppler VOR's not be used for broadcast of AWOS. As a result of this study, the FAA should review the application of other alternatives for broadcast of AWOS.

2. Precipitation sensor studies be continued, particularly alternatives to grid-type detectors. The FAA is now funding such a study and expects HSS Incorporated to issue a report by February 1985.

3. Cloud algorithm development studies be conducted to improve algorithm response and accuracy, particularly during precipitation. The Technical Center is now conducting such a study and will produce a report by February 1985.

APPENDIX A

AUTOMATED WEATHER OBSERVING SYSTEM DEMONSTRATION PROGRAM

DESCRIPTION OF DATA QUALITY CONTROL PROGRAM

AWOS DATA QUALITY CONTROL

GENERAL DESCRIPTION.

This data analysis validates hourly reports received by the Technical Center from the 14 AWOS sites and ascertains whether or not data fall within limits as defined in the AWOS Test Plan. It generates printed reports having the following:

1. Information regarding the retrieval of the data from the AWOS site by the Technical Center.

2. Hourly observations containing errors, with the errors flagged and/or coded.

3. Summaries having counts of all flagged and coded errors, with the error codes defined, and counts of the set/unset condition of flags.

It also creates an intermediate file containing data and error flags from which further analysis can be done

THE PRINTED REPORT.

A sample printout is presented in figure A-1. The header of the printout is the retrieval status information that was generated upon completion of data acquisition and is printed at the beginning of each run of hourly reports. This section includes the date and time of the collection, the amount of data retrieved, internal error reports, and other information pertinent to data management.

The following information is shown in the printout under the appropriate headings.

1. Weather Report Image. Each hourly report that contains an error is printed whether that error is one of input validation, quality control, or system fault diagnostics that were generated remotely at the site. Individual data elements from the hourly report are described in Note A-1. Additional explanation for the sky condition field is provided in Note A-2.

Error conditions, internal status codes, and counters that are generated after acquisition of data at the Technical Center are printed following each of the four hourly reports to which they relate. The input file is structured such that four hourly weather reports are processed as a unit and the related information is included with the same unit. Each byte in an hourly report that has been flagged during acquisition has an asterisk (*) printed below it. Internal status codes and their meanings are defined in Note A-3.

2. Remarks and Status. Remarks and status are coded system fault diagnostic messages that have been added automatically to the hourly reports at the AWOS sites prior to recording. The messages signal sensor related equipment problems. They are designed to facilitate Remote Maintenance Monitoring (RMM). A complete list of codes as they relate to each sensor is contained in Note A-4.

3. Input Validation. Each field of weather data is examined to validate the correct type of data, e.g., numeric fields should have numeric content. Any field not having the correct type of data is flagged.

4. Quality Control: Quality control checks are performed in accordance with the criteria set forth in the AWOS Test Plan. Additional criteria were added and a complete list of quality control checks is listed in Note A-5.

When a quality control failure occurs, an error code indicating the specific failure is assigned to the hourly report and is scheduled for printing. Following each batch of hourly reports is summary information containing:

a. Counts of each quality conrol failure.

b. A count of the number of times each field had invalid data, i.e., unrecognizable.

c. RMM status counts.

d. The number of times an RMM flag is set versus the number of times not set.

THE INTERMEDIATE FILE.

In addition to the printed report, an intermediate file is generated. The intermediate file stores the following fields for each hourly report:

1. The Julian date for the hour's data.

2. That hour's data in integer format.

3. Cloud height (based on the hour's sky condition data).

4. Remarks and status (RMM) fault characters.

5. Input validation characters.

6. Quality control flag characters.

Information stored in the intermediate file can be used to perform further analysis such as the AWOS Versus Official Comparison (analysis 3 in Test Plan).

Note A-1: Data Elements of Printed Report.

1. Weather Report Image.

Field	Description	Format
DATE	Month a day report recorded	MM/DD
STA ID	Identification of site sending data	3 Alpha
GM TM	Greenwich Mean Time	2 Num (HH)

Field	Description	Format
JUL DAT	Julian Date	3 Num (DDD)
SKY CDND	Sky condition (See item 2 below)	11 Alpha/Num
VS	Visibility in units miles and quarters of a mile. ex: 11 = 1 1/4 mile 32 = 3 2/4 miles Less than 1/4 mile is '00' Greater than 5 miles is '55'	2 Num
PRS	Pressure (altimeter setting) in hundredths of inches of mercury	3 Num
TEMP	Temperature in degrees Fahrenheit preceeded by either a sign or blank	4 Alpha/Num
DEW	Dew Point in degrees preceeded by either a sign or a blank	3 Alpha/Num
WND DIR	Wind direction in degrees	3 Num
WND SPD	Wind speed in knots	3 Num
WND GST	Wind gusts in knots	3 Num
DNS ALT	Density altitude in hundreds of feet	3 Num
PCP AMT	Precipitation amount since last report in hundredths of inches	3 Num
PCP TIM	Precipitation time in minutes preceded by flag byte where B = begin, E = end	3 Alpha/Num

2. Remarks and Status (RMM) (See Note A-4)

Field	Description	Format
TP	Temperature	1 Alpha
DP	Dew point	1 Alpha
PR	Pressure	1 Alpha
WD	Wind direction	1 Alpha
WS	Wind speed	1 Alpha

Field	Description	Format
VS	Visibility	1 Alpha
CH	Cloud height	1 Alpha
PC	Precipitation	1 Alpha
SY	Processor/System	1 Alpha

3. Input Validation

Field	Description	Content
HR	Hour of report	T or F*
MN	Minute of report	T or F*
VS	Visibility	T or F*
PR	Pressure	T or F*
TP	Temperature	T or F*
DP	Dew point	T or F*
WD	Wind direction	T or F*
WS	Wind speed	T or F*
WG	Wind gusts	T or F*
DA	Density altitude	T or F*
PA	Precipitation amount	T or F*
PT	Precipitation time	T or F*
V-	Variable visibility minimum	T or F*
V+	Variable visibility maximum	T or F*
C-	Variable ceiling height minimum	T or F*
C+	Variable ceiling height maximum	T or F*
CH	Cloud height	T or F*

4. Quality Control Failures

Field	Description	Format
Quality control failures	Alphabetic codes indicating failure of data to meet specific quality control parameters (see Note A-5)	15 Num

*True/False flags in the form of 'T' or 'F' indicating the presence of valid or invalid data. Used only when one or more fields are invalid.

Note A-2: Sky Condition.

Sky condition consists of eleven alphanumeric positions with data left justified and unused bytes having blanks.

Examples follow:

Column	9	10	11	12	13	14	15	16	17	18	19
	3	0	S	M	4	5	B	-	-	-	-
	1	5	S	2	5	S	E	4	0	0	-
	C	L	R	-	-	-	-	-	-	-	-
	C	L	R	-	-	F	E	W	-	4	5
	W	2	X	-	-	-	-	-	-	-	-
	X	1	2	S	2	6	S	M	3	5	B

Cloud layers are reported as XYC where:

X = height in thousands of feet
Y = height in hundreds of feet
C = S Scattered
B Broken
O Overcast

Cloud layers can also have a prefix:

F = Estimated
M = Measured

Partially obscured sky will have 'X' in the first position, and totally obscured sky will have 'W' in the first position.

Totally obscured sky will be represented by WAX where:

A = 1 if visibility is less than or equal 1/4 mile
2 if visibility is greater than 1/4 mile and less than 1 1/2 miles
7 if visibility is greater than or equal 1 1/2 miles and less than 2 miles and the air temperature is less than or equal to 36 °F.

"A" is the vertical visibility in hundreds of feet and
is considered the ceiling height.

Order of reporting cloud layers:

Lowest scattered layer (SCT)
Lowest broken layer (BKN)
Overcast layer (DVC), only one overcast layer is reporteded
Second lowest scattered layer (SCT)
Second lowest broken layer (BKN)
Highest broken layer (BKN)
Highest scattered layer (SCT)

Note A-3: <u>Internal Status Codes.</u>

Asterisk (*) under any field indicates invalid input that was discovered upon receipt of the data at the Technical Center.

A dotted line (.........) in the "Remarks and Status" column also indicates an error was found on receiving the data from the site.

To the right of the dotted line, and on succeeding lines, if necessary, will be:

STATUS
- 8001 AWOS STATION PROCESSOR ERROR
- 8002 FRAMING DATA LIMIT ERROR
- 8004 FRAMING DATA PARITY ERROR
- 8008 STATION ID ERROR
- 8010 END OF STATION'S DATA CODE
- 8020 TIME-OUT CODE
- 8040 BAD DATA CODE

PARITY ERROR COUNT
DATA LIMIT ERROR COUNT
TOTAL DATA ERROR COUNT
FIRST ERROR BYTE SLOT AND CODE
SECOND ERROR BYTE SLOT AND CODE
SECOND ERROR BYTE SLOT AND CODE
SECOND ERROR BYTE SLOT AND CODE
SECOND ERROR BYTE SLOT AND CODE
EIGHTY-FOURTH ERROR BYTE SLOT AND CODE

ERROR BYTE SLOT CODE FORMAT:

- 1XXX PARITY ERROR COLUMN XXX
- 2XXX DATA MATCH ERROR COLUMN XXX
- 4XXX DATA LIMIT ERROR COLUMN XXX

Columns referred to will be the same positions that have asterisks under them in the four reports immediately preceding the line of coded errors.

[illegible] <u>Remarks and Status (RMM).</u>

Field	Status Codes and Meanings
TP	Temperature

A = Sensor data not within limits
B = Insufficient data to generate a recorded value
C = Any sensor error detected since last report
D = Greater than 6 °F change in 1 minute since last report.

DP — Dew Point

A, B, C, D same as for temperature
E = Dew Point greater than temperature by 1 °F or 2 °F
F = Dew Point greater than temperature by more than 2 °F

PR — Pressure

A, B, C same as for temperature, sensor 1
D, E, F same as A, B, C, but for sensor 2
G Pressure readings from both sensors not within 0.04 inches of previous readings since last report
P = Precipitation occurrence timeter setting

WD — Wind Direction

A, B, C same as for temperature

WS — Wind Speed

A, B, C same as for temperature

VS — Visibility

A, B, C same as for temperature
V = Variable

CH — Cloud Height

A, B, C same as for temperature
D = "HIR CLDS VSB"
E = "BKN VRBL SCT"
F = "BKN VRBL OVC"
G = "OVC VRBL BKN"

PC — Precipitation

A, B, C same as for temperature, precipitation occurrence sensor
D, E, F same as for A, B, C but precipitation amount sensor
P = Precipitation occurrence

TABLE B-[illegible]. SYSTEM AND SENSOR DATA FOR KEENE, N. H. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	60.17	0	659.83	6	109.97
9/83 - 10/83	1440	68.89	0.25	1370.86	8	171.36
9/83 - 11/83	2160	69.24	0.25	2090.51	11	190.05
9/83 - 12/83	2880	74.41	0.25	2805.34	12	233.78
9/83 - 1/84	3600	74.41	0.25	3525.34	12	293.78
9/83 - 2/84	4320	74.41	0.25	4245.34	12	353.78
9/83 - 3/84	5040	74.41	0.25	4965.34	12	413.78
9/83 - 4/84	5760	74.41	0.25	5685.34	12	473.78
9/83 - 5/84	6480	74.41	0.25	6405.34	12	533.78
9/83 - 6/84	7200	74.41	0.25	7125.34	12	593.78

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	25.25	1414.75	0	
9/83 - 11/83	2160	0	102.50	2057.50	0	
9/83 - 12/83	2880	0	102.50	2777.50	0	
9/83 - 1/84	3600	0	102.50	3497.50	0	
9/83 - 2/84	4320	0	102.50	4217.50	0	
9/83 - 3/84	5040	0	102.50	4937.50	0	
9/83 - 4/84	5760	0	102.50	5657.50	0	
9/83 - 5/84	6480	0	102.50	6377.50	0	
9/83 - 6/84	7200	0	102.50	7097.50	0	

TABLE B-3. SYSTEM AND SENSOR DATA FOR KEENE, N. H.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	720.00	0	
9/83 - 10/83	1440	25.25	1414.75	2	707.38
9/83 - 11/83	2160	102.50	2057.50	3	685.83
9/83 - 12/83	2880	102.50	2777.50	3	925.83
9/83 - 1/84	3600	102.50	3497.50	3	1165.83
9/83 - 2/84	4320	104.00	4216.00	3	1405.33
9/83 - 3/84	5040	104.00	4936.00	3	1645.33
9/83 - 4/84	5760	104.00	5656.00	3	1885.33
9/83 - 5/84	6480	104.00	6376.00	3	2125.33
9/83 - 6/84	7200	104.00	7096.00	3	2365.33

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0.25	0	719.75	1	
9/83 - 10/83	1440	0.25	0	1439.75	1	
9/83 - 11/83	2160	1.00	0	2159.00	2	1079.50
9/83 - 12/83	2880	1.00	0	2879.00	2	1439.50
9/83 - 1/84	3600	1.00	0	3599.00	2	1799.50
9/83 - 2/84	4320	1.00	0	4319.00	2	2159.50
9/83 - 3/84	5040	1.00	0	5039.00	2	2519.50
9/83 - 4/84	5760	1.00	0	5759.00	2	2879.50
9/83 - 5/84	6480	1.00	0	6479.00	2	3239.50
9/83 - 6/84	7200	2.17	0	7197.83	2	3598.92

TABLE B-2. SYSTEM AND SENSOR DATA FOR HOUSTON, TEXAS (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	1	0	719.00	1	
9/83 - 10/83	1440	1	0	1439.00	1	
9/83 - 11/83	2160	1	0	2159.00	1	
9/83 - 12/83	2880	1	0	2879.00	1	
9/83 - 1/84	3600	1	0	3599.00	1	
9/83 - 2/84	4320	1	0	4319.00	1	
9/83 - 3/84	5040	1	0	5039.00	1	
9/83 - 4/84	5760	1	0	5759.00	1	
9/83 - 5/84	6480	1	0	6479.00	1	
9/83 - 6/84	7200	1	0	7199.00	1	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	1	3599.00	0	
9/83 - 2/84	4320	0	1	4319.00	0	
9/83 - 3/84	5040	0	1	5039.00	0	
9/83 - 4/84	5760	0	1	5759.00	0	
9/83 - 5/84	6480	0	1	6479.00	0	
9/83 - 6/84	7200	25.20	1	7173.80	1	

TABLE B-2. SYSTEM AND SENSOR DATA FOR HOUSTON, TEXAS (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-2. SYSTEM AND SENSOR DATA FOR HOUSTON, TEXAS (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	3	0	2157.00	1	
9/83 - 12/83	2880	3	0	2877.00	1	
9/83 - 1/84	3600	3	0	3597.00	1	
9/83 - 2/84	4320	3	0	4317.00	1	
9/83 - 3/84	5040	3	0	5037.00	1	
9/83 - 4/84	5760	3	0	5757.00	1	
9/83 - 5/84	6480	3	0	6477.00	1	
9/83 - 6/84	7200	3	0	7197.00	1	

TABLE B-2. SYSTEM AND SENSOR DATA FOR HOUSTON, TEXAS

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	720.00	0	
9/83 - 10/83	1440	0	1440.00	0	
9/83 - 11/83	2160	0	2160.00	0	
9/83 - 12/83	2880	0	2880.00	0	
9/83 - 1/84	3600	1.00	3599.00	1	
9/83 - 2/84	4320	1.00	4319.00	1	
9/83 - 3/84	5040	1.00	5039.00	1	
9/83 - 4/84	5760	1.00	5759.00	1	
9/83 - 5/84	6480	1.00	6479.00	1	
9/83 - 6/84	7200	1.00	7199.00	1	

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	1.00	0	1439.00	1	
9/83 - 11/83	2160	1.00	0	2159.00	1	
9/83 - 12/83	2880	1.00	0	2879.00	1	
9/83 - 1/84	3600	1.00	0	3599.00	1	
9/83 - 2/84	4320	1.00	0	4319.00	1	
9/83 - 3/84	5040	1.00	0	5039.00	1	
9/83 - 4/84	5760	346.00	0	5414.00	2	2707.00
9/83 - 5/84	6480	607.25	0	5872.75	2	2936.38
9/83 - 6/84	7200	607.25	0	6592.75	2	3296.38

TABLE B-1. SYSTEM AND SENSOR DATA FOR AUBURN, ALA. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	40.00	680.00	0	
9/83 - 10/83	1440	0	40.00	1400.00	0	
9/83 - 11/83	2160	0	40.00	2120.00	0	
9/83 - 12/83	2880	0	40.00	2840.00	0	
9/83 - 1/84	3600	0	40.00	3560.00	0	
9/83 - 2/84	4320	0	40.00	4280.00	0	
9/83 - 3/84	5040	0	40.00	5000.00	0	
9/83 - 4/84	5760	0	40.00	5720.00	0	
9/83 - 5/84	6480	0	40.00	6440.00	0	
9/83 - 6/84	7200	0	40.00	7160.00	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-1. SYSTEM AND SENSOR DATA FOR AUBURN, ALA. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	40.00	680.00	0	
9/83 - 10/83	1440	0	40.00	1400.00	0	
9/83 - 11/83	2160	0	40.00	2120.00	0	
9/83 - 12/83	2880	0	40.00	2840.00	0	
9/83 - 1/84	3600	0	40.00	3560.00	0	
9/83 - 2/84	4320	0	40.00	4280.00	0	
9/83 - 3/84	5040	0	40.00	5000.00	0	
9/83 - 4/84	5760	0	40.00	5720.00	0	
9/83 - 5/84	6480	0	40.00	6440.00	0	
9/83 - 6/84	7200	0	67.50	7132.50	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	40.00	680.00	0	
9/83 - 10/83	1440	0	40.00	1400.00	0	
9/83 - 11/83	2160	0	40.00	2120.00	0	
9/83 - 12/83	2880	0	40.00	2840.00	0	
9/83 - 1/84	3600	0	40.00	3560.00	0	
9/83 - 2/84	4320	0	40.00	4280.00	0	
9/83 - 3/84	5040	0	40.00	5000.00	0	
9/83 - 4/84	5760	0	40.00	5720.00	0	
9/83 - 5/84	6480	0	40.00	6440.00	0	
9/83 - 6/84	7200	0	67.50	7132.50	0	

TABLE B-1. SYSTEM AND SENSOR DATA FOR AUBURN, ALA. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	7.08	2872.92	0	
9/83 - 1/84	3600	0	7.08	3592.92	0	
9/83 - 2/84	4320	0	7.08	4312.92	0	
9/83 - 3/84	5040	0	321.08	4718.92	0	
9/83 - 4/84	5760	0	321.08	5438.92	0	
9/83 - 5/84	6480	0	321.08	6158.92	0	
9/83 - 6/84	7200	0	321.08	6878.92	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	40.00	680.00	0	
9/83 - 10/83	1440	0	40.00	1400.00	0	
9/83 - 11/83	2160	0	40.00	2120.00	0	
9/83 - 12/83	2880	0	40.00	2840.00	0	
9/83 - 1/84	3600	0	40.00	3560.00	0	
9/83 - 2/84	4320	0	40.00	4280.00	0	
9/83 - 3/84	5040	0	40.00	5000.00	0	
9/83 - 4/84	5760	0	40.00	5720.00	0	
9/83 - 5/84	6480	0	40.00	6440.00	0	
9/83 - 6/84	7200	0	40.00	7160.00	0	

TABLE B-1. SYSTEM AND SENSOR DATA FOR AUBURN, ALA.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	40.00	680.00	1	
9/83 - 10/83	1440	40.25	1399.75	2	699.88
9/83 - 11/83	2160	40.25	2119.75	2	1059.88
9/83 - 12/83	2880	47.33	2832.67	3	944.22
9/83 - 1/84	3600	47.33	3552.67	3	1184.22
9/83 - 2/84	4320	47.33	4272.67	3	1424.22
9/83 - 3/84	5040	361.33	4678.67	4	1169.67
9/83 - 4/84	5760	361.33	5398.67	4	1349.67
9/83 - 5/84	6480	361.33	6118.67	4	1529.67
9/83 - 6/84	7200	388.83	6811.17	5	1362.23

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	314.00	4726.00	0	
9/83 - 4/84	5760	0	314.00	5446.00	0	
9/83 - 5/84	6480	0	314.00	6166.00	0	
9/83 - 6/84	7200	0	341.50	6858.50	0	

APPENDIX B

AUTOMATED WEATHER OBSERVING SYSTEM DEMONSTRATION PROGRAM

TABLES OF TOTAL OPERATING TIME
AND
ESTIMATED VALUES OF MEAN-TIME-BETWEEN-FAILURES

```
SYSTIME = 12:37:28  SYSDATE = 05/24/84  LAST SECTOR =     13  TOTAL OK =      0
TOTAL TRIES =      7  REWIND (0 = YES) =      0  INDIVIDUAL REPORT POINTER =
REPORTS FOR MESSAGES 1 THRU 37 FOLLOW IN HEXADECIMAL:
101    0 140    1    0 140    1    0 140    1    0 140    1    0 140 3002    0    4
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

              W E A T H E R   R E P O R T   I M A G E                 REMARKS
               ENDING 05/24/84                  12:37:28               & STATUS

     ST GM JUL                                  WND WND WND DNS PCP PCP TDPWWVCPS
DATE ID TM DAT SKY COND       VS PRS TEMP DEW DIR SPD GST ALT AMT TIM PPRDSSHCY
                              2  2   2     3   3   4   4   4   5   5   6
      1  4 6  9               1  4   8     3   7   1   5   9   3   7   1

05/23

      CMX14523CLR             55 999   51   31 310  17
      CMX15523                   000                                   BB BBBBBE
      CMX16523CLR             55 999   54   30 290  15  21
      CMX17523CLR             55 000   57   29 260  16


      CMX18523CLR             55 998   59   29 270  15  22
      CMX19523CLR             55 996   62   27 250  16  26  15
      CMX20523CLR             55 994   64   30 250  19  25  16
      CMX21523CLR             55 992   66   31 260  13  29  18
      CMX22523CLR             55 991   64   31 260  15  21  17
      CMX23523CLR             55 991   66   32 260  15  22  18

05/24

      CMX00524CLR             55 992   64   31 270  12  22  17
      CMX01524CLR             55 991   61   32 270  11  16  15
      CMX02524CLR             55 993   59   33 290  06
      CMX03524CLR             55 993   57   32 270  08
      CMX04524CLR             55 993   56   33 270  07
      CMX05524CLR             55 993   57   33 270  06
      CMX06524CLR             55 993   56   34 270  07
      CMX07524CLR             55 991   57   33 260  07
      CMX08524CLR             55 989   53   33 270  05
      CMX09524CLR             55 987   53   35 00   00

******  05/24/84  WEATHER REPORT SUMMARY    20 HOURLY REPORTS PROCESSED   *****

             QUALITY CONTROL FAILURES ON AWOS REPORTS
 ERROR
 COUNT   CODE    MEANING

   19      A    TIME DIF < 50 OR > 75 MIN.
    2      C    TEMP CHANGE > 6 DEG F.
    2      D    DP CHANGE > 3 DEG F.
    2      E    WIND SPD CHANGE > 10 KNOTS
    3      H    WIND GST CHANGE > 20 KTS
    1      J    TEMP NOT NORMAL FOR AREA
    2      O    DNS ALT CHG EQ OR > 300 FT

 INPUT VALIDATION ERRORS

 COUNT   DATA FIELD
   20    VAR CEIL HT MAX

REMOTE MAINTENANCE MONITORING (REMARKS & STATUS)
 SENSOR  COUNT  CODE  MEANING

  TEMP      1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  D P       1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  W D       1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  W S       1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  VIS       1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  CLD       1      B    INSUFFICIENT DATA TO GENERATE A VALUE
  PREC      1      B    PRECIPITATION OCCURRENCE SENSOR INSUFFICIENT DATA TO GENE
  SYS       1      E    COMM FAILURE TO SENSOR GROUP 1

  RMM FLAG COUNTS
   SENSOR      SET    UNSET
    TEMP        1       19
    D P         1       19
    PRES        0       20
    W D         1       19
    W S         1       19
    VIS         1       19
    CLD         1       19
    PREC        1       19
    SYS         1       19
         END OF AWOS PROCESSING...NO MORE DATA
       ABSLOUTE END OF AWOSQ2 PROGRAM, NO MORE DATA
```

M — Cloud height is less than 500 feet and visibility is greater than 1 mile.

N — Cloud height is greater than 500 feet and visibility is less than 1 mile.

O — Density altitude change between current report and 1 hour earlier is greater than or equal to 300 feet.

P — Temperature exceeds dew point by 12° or more and ceiling is less than or equal to 500 feet.

Q — Temperature exceeds dew point by 12° or more and the sky is obscured, or visibility is less than or equal to 1 mile.

R — More than two consecutive hourly reports having ceiling height less than or equal to 200 feet and visibility greater than 4 miles.

S — "E" for estimated preceding clear or scattered sky condition.

T — Wind speed less than 6 knots with gusts.

U — Obscuration with visibility greater than or equal to 3 miles.

V — Pressure less than 26.00 or greater than 32.99 inches.

SY Processor/System

A = Power supply 1 out of tolerance
B = Power supply 2 out of tolerance
C = Power supply 3 out of tolerance
D = Power supply 4 out of tolerance
E = Communication failure to sensor group 1
F = Communication failure to sensor group 2
G = Communication failure to sensor group 3
H = Equipment temperature too high
I = Equipment temperature too low
J = RAM memory failure
K = Archive device failure

Code 'A' has the highest priority. Priority decreases as successive letters of the alphabet are utilized. Only the highest priority code will be used.

Note A-5: Quality Control Failures.

Code	Meaning
A	Time difference between current report and that of 1 hour earlier is less than 50 or greater than 75 minutes.
B	Altimeter change between current report and 1 hour earlier is greater than 0.05 inches.
C	Temperature change between current report and 1 hour earlier is greater than 6 °F.
D	Dew Point change between current report and 1 hour earlier is greater than 3 °F
E	Wind speed change between current report and 1 hour earlier is greater than 10 knots.
F	Wind direction change between current report and 1 hour earlier is greater than 60° while wind speed of both current and prior reports is greater than 10 knots.
G	Precipitation quantity is greater than 0.5 inches.
H	Wind gusts change between current report and 1 hour earlier is greater than 20 knots.
I	Wind speed is greater than 25 knots.
J	Temperature is outside of the normal range for the site for the date being reported.
L	Dew point is greater than temperature

TABLE B-3. SYSTEM AND SENSOR DATA FOR KEENE, N. H. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	25.00	1415.00	0	
9/83 - 11/83	2160	0	102.25	2057.75	0	
9/83 - 12/83	2880	0	102.25	2777.75	0	
9/83 - 1/84	3600	0	102.25	3497.75	0	
9/83 - 2/84	4320	0	102.25	4217.75	0	
9/83 - 3/84	5040	0	102.25	4937.75	0	
9/83 - 4/84	5760	0	102.25	5657.75	0	
9/83 - 5/84	6480	0	102.25	6377.75	0	
9/83 - 6/84	7200	0	102.25	7097.50	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	25.00	1415.00	0	
9/83 - 11/83	2160	0	102.25	2057.75	0	
9/83 - 12/83	2880	0	102.25	2777.75	0	
9/83 - 1/84	3600	0	102.25	3497.75	0	
9/83 - 2/84	4320	0	102.25	4217.75	0	
9/83 - 3/84	5040	0	102.25	4937.75	0	
9/83 - 4/84	5760	0	102.25	5657.75	0	
9/83 - 5/84	6480	0	102.25	6377.75	0	
9/83 - 6/84	7200	0	102.25	7097.50	0	

TABLE B-3. SYSTEM AND SENSOR DATA FOR KEENE, N. H. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	27.00	0	2133.00	1	
9/83 - 12/83	2880	27.00	0	2853.00	1	
9/83 - 1/84	3600	31.00	0	3569.00	2	1784.50
9/83 - 2/84	4320	31.00	0	4289.00	2	2144.50
9/83 - 3/84	5040	31.00	0	5009.00	2	2504.50
9/83 - 4/84	5760	31.00	0	5729.00	2	2864.50
9/83 - 5/84	6480	31.00	0	6449.00	2	3224.50
9/83 - 6/84	7200	31.00	0	7169.00	2	3584.50

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	54.58	0	2105.42	1	
9/83 - 12/83	2880	54.58	0	2825.42	1	
9/83 - 1/84	3600	55.58	0	3544.42	2	1772.21
9/83 - 2/84	4320	55.58	0	4264.42	2	2132.21
9/83 - 3/84	5040	55.58	0	4984.42	2	2492.21
9/83 - 4/84	5760	55.58	0	5704.42	2	2852.21
9/83 - 5/84	6480	55.58	0	6424.42	2	3212.21
9/83 - 6/84	7200	55.58	0	7144.42	2	3572.21

TABLE B-4. SYSTEM AND SENSOR DATA FOR MUNCIE, IND.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	2.17	717.83	1	
9/83 - 10/83	1440	2.17	1437.83	1	
9/83 - 11/83	2160	2.17	2157.83	1	
9/83 - 12/83	2880	2.17	2877.83	1	
9/83 - 1/84	3600	2.17	3597.83	1	
9/83 - 2/84	4320	2.17	4317.83	1	
9/83 - 3/84	5040	2.17	5037.83	1	
9/83 - 4/84	5760	2.17	5757.83	1	
9/83 - 5/84	6480	2.17	6477.83	1	
9/83 - 6/84	7200	3.07	7196.93	1	

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0.25	0	1439.75	1	
9/83 - 11/83	2160	676.25	0	1483.75	2	741.88
9/83 - 12/83	2880	1396.25	0	1483.75	2	741.88
9/83 - 1/84	3600	2116.25	0	1483.75	2	741.88
9/83 - 2/84	4320	2836.25	0	1483.75	2	741.88
9/83 - 3/84	5040	3556.25	0	1483.75	2	741.88
9/83 - 4/84	5760	4276.25	0	1483.75	2	741.88
9/83 - 5/84	6480	4996.25	0	1483.75	2	741.88
9/83 - 6/84	7200	5716.25	0	1483.75	2	741.88

TABLE B-4. SYSTEM AND SENSOR DATA FOR MUNCIE, IND. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	1.00	0	4319.00	0	
9/83 - 3/84	5040	1.00	0	5039.00	0	
9/83 - 4/84	5760	1.00	0	5759.00	0	
9/83 - 5/84	6480	1.00	0	6479.00	0	
9/83 - 6/84	7200	1.30	0	7198.70	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	2.17	717.83	0	
9/83 - 10/83	1440	0	2.17	1437.83	0	
9/83 - 11/83	2160	0	2.17	2157.83	0	
9/83 - 12/83	2880	0	2.17	2877.83	0	
9/83 - 1/84	3600	0	2.17	3597.83	0	
9/83 - 2/84	4320	0	2.17	4317.83	0	
9/83 - 3/84	5040	0	2.17	5037.83	0	
9/83 - 4/84	5760	0	2.17	5757.83	0	
9/83 - 5/84	6480	0	2.17	6477.83	0	
9/83 - 6/84	7200	0.30	2.17	7197.53	0	

TABLE B-4. SYSTEM AND SENSOR DATA FOR MUNCIE, IND. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	2.17	717.83	0	
9/83 - 10/83	1440	0	2.17	1437.83	0	
9/83 - 11/83	2160	0	2.17	2157.83	0	
9/83 - 12/83	2880	0	2.17	2877.83	0	
9/83 - 1/84	3600	0	2.17	3597.83	0	
9/83 - 2/84	4320	0	2.17	4317.83	0	
9/83 - 3/84	5040	0	2.17	5037.83	0	
9/83 - 4/84	5760	0	2.17	5757.83	0	
9/83 - 5/84	6480	196.58	2.17	6281.25	2	3140.63
9/83 - 6/84	7200	196.88	2.17	7000.95	2	3500.48

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	2.17	717.83	0	
9/83 - 10/83	1440	0	2.17	1437.83	0	
9/83 - 11/83	2160	0	2.17	2157.83	0	
9/83 - 12/83	2880	3.00	2.17	2874.83	1	
9/83 - 1/84	3600	3.00	2.17	3594.83	1	
9/83 - 2/84	4320	3.00	2.17	4314.83	1	
9/83 - 3/84	5040	3.00	2.17	5034.83	1	
9/83 - 4/84	5760	3.00	2.17	5754.83	1	
9/83 - 5/84	6480	3.00	2.17	6474.83	1	
9/83 - 6/84	7200	3.30	2.17	7194.53	1	

TABLE B-4. SYSTEM AND SENSOR DATA FOR MUNCIE, IND. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	2.17	717.83	0	
9/83 - 10/83	1440	1.00	2.17	1436.83	1	
9/83 - 11/83	2160	1.00	2.17	2156.83	1	
9/83 - 12/83	2880	482.00	2.17	2395.83	2	1197.92
9/83 - 1/84	3600	482.00	2.17	3115.83	2	1557.92
9/83 - 2/84	4320	482.00	2.17	3835.83	2	1917.92
9/83 - 3/84	5040	482.00	2.17	4555.83	2	2277.92
9/83 - 4/84	5760	482.00	2.17	5275.83	2	2637.92
9/83 - 5/84	6480	482.00	2.17	5995.83	2	2997.92
9/83 - 6/84	7200	482.30	2.17	6715.53	2	3357.77

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0.30	0	7199.70	0	

TABLE B-5. SYSTEM AND SENSOR DATA FOR PALM SPRINGS, CALIF.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	720.00	0	
9/83 - 10/83	1440	0	1440.00	0	
9/83 - 11/83	2160	2.05	2157.95	2	1078.98
9/83 - 12/83	2880	2.05	2877.95	2	1438.98
9/83 - 1/84	3600	2.05	3597.95	2	1798.98
9/83 - 2/84	4320	2.05	4317.95	2	2158.98
9/83 - 3/84	5040	2.05	5037.95	2	2518.98
9/83 - 4/84	5760	2.05	5757.95	2	2878.98
9/83 - 5/84	6480	2.05	6477.95	2	3238.98
9/83 - 6/84	7200	2.05	7197.95	2	3598.98

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	1.05	2158.95	0	
9/83 - 12/83	2880	0	1.05	2878.95	0	
9/83 - 1/84	3600	0	1.05	3598.95	0	
9/83 - 2/84	4320	0	1.05	4318.95	0	
9/83 - 3/84	5040	0	1.05	5038.95	0	
9/83 - 4/84	5760	0	1.05	5758.95	0	
9/83 - 5/84	6480	0.10	1.05	6478.85	1	
9/83 - 6/84	7200	0.10	1.05	7198.85	1	

TABLE B-5. SYSTEM AND SENSOR DATA FOR PALM SPRINGS, CALIF. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	3.00	1.05	2155.95	1	
9/83 - 12/83	2880	3.00	1.05	2875.95	1	
9/83 - 1/84	3600	3.00	1.05	3595.95	1	
9/83 - 2/84	4320	3.00	1.05	4315.95	1	
9/83 - 3/84	5040	3.00	1.05	5035.95	1	
9/83 - 4/84	5760	3.00	1.05	5755.95	1	
9/83 - 5/84	6480	3.00	1.05	6475.95	1	
9/83 - 6/84	7200	3.00	1.05	7195.95	1	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	1	2159.00	0	
9/83 - 12/83	2880	0	1	2879.00	0	
9/83 - 1/84	3600	0	1	3599.00	0	
9/83 - 2/84	4320	0	1	4319.00	0	
9/83 - 3/84	5040	0	1	5039.00	0	
9/83 - 4/84	5760	0	1	5759.00	0	
9/83 - 5/84	6480	0	1	6479.00	0	
9/83 - 6/84	7200	0	1	7199.00	0	

TABLE B-5. SYSTEM AND SENSOR DATA FOR PALM SPRINGS, CALIF. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	1	2159.00	0	
9/83 - 12/83	2880	0	1	2879.00	0	
9/83 - 1/84	3600	0	1	3599.00	0	
9/83 - 2/84	4320	0	1	4319.00	0	
9/83 - 3/84	5040	0	1	5039.00	0	
9/83 - 4/84	5760	0	1	5759.00	0	
9/83 - 5/84	6480	0	1	6479.00	0	
9/83 - 6/84	7200	0	1	7199.00	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	1	2159.00	0	
9/83 - 12/83	2880	0	1	2879.00	0	
9/83 - 1/84	3600	0	1	3599.00	0	
9/83 - 2/84	4320	0	1	4319.00	0	
9/83 - 3/84	5040	0	1	5039.00	0	
9/83 - 4/84	5760	0	1	5759.00	0	
9/83 - 5/84	6480	0	1	6479.00	0	
9/83 - 6/84	7200	0	1	7199.00	0	

TABLE B-5. SYSTEM AND SENSOR DATA FOR PALM SPRINGS, CALIF. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	1	2159.00	0	
9/83 - 12/83	2880	0	1	2879.00	0	
9/83 - 1/84	3600	0	1	3599.00	0	
9/83 - 2/84	4320	0	1	4319.00	0	
9/83 - 3/84	5040	0	1	5039.00	0	
9/83 - 4/84	5760	0	1	5759.00	0	
9/83 - 5/84	6480	0	1	6479.00	0	
9/83 - 6/84	7200	0	1	7199.00	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-6. SYSTEM AND SENSOR DATA FOR SAN LOUIS OBISPO, CALIF.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	49.42	670.58	1	
9/83 - 10/83	1440	144.42	1295.58	3	431.86
9/83 - 11/83	2160	144.42	2015.58	3	671.86
9/83 - 12/83	2880	144.42	2735.58	3	911.86
9/83 - 1/84	3600	144.42	3455.58	3	1151.86
9/83 - 2/84	4320	144.42	4175.58	3	1391.86
9/83 - 3/84	5040	144.42	4895.58	3	1631.86
9/83 - 4/84	5760	144.42	5615.58	3	1871.86
9/83 - 5/84	6480	144.42	6335.58	3	2111.86
9/83 - 6/84	7200	144.42	7055.58	3	2351.86

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0.67	1439.33	0	
9/83 - 11/83	2160	0	0.67	2159.33	0	
9/83 - 12/83	2880	0	0.67	2879.33	0	
9/83 - 1/84	3600	0	0.67	3599.33	0	
9/83 - 2/84	4320	0	0.67	4319.33	0	
9/83 - 3/84	5040	0	0.67	5039.33	0	
9/83 - 4/84	5760	0	0.67	5759.33	0	
9/83 - 5/84	6480	0	0.67	6479.33	0	
9/83 - 6/84	7200	0	0.67	7199.33	0	

TABLE B-6. SYSTEM AND SENSOR DATA FOR SAN LOUIS OBISPO, CALIF. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0.67	1439.33	0	
9/83 - 11/83	2160	2.17	0.67	2157.16	2	1078.58
9/83 - 12/83	2880	4.17	0.67	2875.16	3	958.39
9/83 - 1/84	3600	4.17	0.67	3595.16	3	1198.39
9/83 - 2/84	4320	4.17	0.67	4315.16	3	1438.39
9/83 - 3/84	5040	4.17	0.67	5035.16	3	1678.39
9/83 - 4/84	5760	4.17	0.67	5755.16	3	1918.39
9/83 - 5/84	6480	4.17	0.67	6475.16	3	2158.39
9/83 - 6/84	7200	4.17	0.67	7195.16	3	2398.39

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	49.42	670.58	0	
9/83 - 10/83	1440	0	143.75	1296.25	0	
9/83 - 11/83	2160	0	143.75	2016.25	0	
9/83 - 12/83	2880	0	143.75	2736.25	0	
9/83 - 1/84	3600	0	143.75	3456.25	0	
9/83 - 2/84	4320	0	143.75	4176.25	0	
9/83 - 3/84	5040	0	143.75	4896.25	0	
9/83 - 4/84	5760	0	143.75	5616.25	0	
9/83 - 5/84	6480	0	143.75	6336.25	0	
9/83 - 6/84	7200	0	143.75	7056.25	0	

TABLE B-6. SYSTEM AND SENSOR DATA FOR SAN LOUIS OBISPO, CALIF. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	49.42	670.58	0	
9/83 - 10/83	1440	0	143.75	1296.25	0	
9/83 - 11/83	2160	0	143.75	2016.25	0	
9/83 - 12/83	2880	0	143.75	2736.25	0	
9/83 - 1/84	3600	0	143.75	3456.25	0	
9/83 - 2/84	4320	0	143.75	4176.25	0	
9/83 - 3/84	5040	0	143.75	4896.25	0	
9/83 - 4/84	5760	0	143.75	5616.25	0	
9/83 - 5/84	6480	0	143.75	6336.25	0	
9/83 - 6/84	7200	0	143.75	7056.25	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	49.42	670.58	0	
9/83 - 10/83	1440	0	143.75	1296.25	0	
9/83 - 11/83	2160	0	143.75	2016.25	0	
9/83 - 12/83	2880	0	143.75	2736.25	0	
9/83 - 1/84	3600	0	143.75	3456.25	0	
9/83 - 2/84	4320	0	143.75	4176.25	0	
9/83 - 3/84	5040	0	143.75	4896.25	0	
9/83 - 4/84	5760	0	143.75	5616.25	0	
9/83 - 5/84	6480	0	143.75	6336.25	0	
9/83 - 6/84	7200	0	143.75	7056.25	0	

TABLE B-6. SYSTEM AND SENSOR DATA FOR SAN LOUIS OBISPO, CALIF. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	49.42	670.58	0	
9/83 - 10/83	1440	0	143.75	1296.25	0	
9/83 - 11/83	2160	0	143.75	2016.25	0	
9/83 - 12/83	2880	0	143.75	2736.25	0	
9/83 - 1/84	3600	0	143.75	3456.25	0	
9/83 - 2/84	4320	0	143.75	4176.25	0	
9/83 - 3/84	5040	0	143.75	4896.25	0	
9/83 - 4/84	5760	0	143.75	5616.25	0	
9/83 - 5/84	6480	0	143.75	6336.25	0	
9/83 - 6/84	7200	0	143.75	7056.25	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-10. SYSTEM AND SENSOR DATA FOR HOUMA, LA. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	313.35	406.65	0	
9/83 - 10/83	1440	0	463.52	976.48	0	
9/83 - 11/83	2160	0.50	597.55	1561.95	1	
9/83 - 12/83	2880	44.50	597.55	2237.95	5	447.59
9/83 - 1/84	3600	44.50	597.55	2957.95	5	591.59
9/83 - 2/84	4320	44.90	597.55	3677.55	6	612.93
9/83 - 3/84	5040	44.90	597.55	4397.55	6	732.93
9/83 - 4/84	5760	44.90	597.95	5117.15	6	852.86
9/83 - 5/84	6480	44.90	597.95	5837.15	6	972.86
9/83 - 6/84	7200	44.90	607.62	6547.48	6	1091.25

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	338.65	387.35	0	
9/83 - 10/83	1440	0	448.82	951.18	0	
9/83 - 11/83	2160	0	622.85	1537.15	0	
9/83 - 12/83	2880	0	622.85	2257.15	0	
9/83 - 1/84	3600	0	622.85	2977.15	0	
9/83 - 2/84	4320	0	622.85	3697.15	0	
9/83 - 3/84	5040	0	622.85	4417.15	0	
9/83 - 4/84	5760	0	622.85	5137.15	0	
9/83 - 5/84	6480	0	622.85	5857.15	0	
9/83 - 6/84	7200	0	632.52	6567.48	0	

TABLE B-10. SYSTEM AND SENSOR DATA FOR HOUMA, LA.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	338.65	381.35	11	34.67
9/83 - 10/83	1440	488.82	951.18	28	33.97
9/83 - 11/83	2160	622.85	1537.15	50	30.74
9/83 - 12/83	2880	622.85	2257.15	50	45.14
9/83 - 1/84	3600	622.85	2977.15	50	59.43
9/83 - 2/84	4320	626.65	3693.35	51	72.42
9/83 - 3/84	5040	626.65	4413.35	51	86.54
9/83 - 4/84	5760	627.45	5132.55	53	96.84
9/83 - 5/84	6480	627.45	5852.55	53	110.43
9/83 - 6/84	7200	637.12	6562.88	54	121.53

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	313.35	406.65	0	
9/83 - 10/83	1440	0	463.52	976.48	0	
9/83 - 11/83	2160	0	597.55	1562.45	0	
9/83 - 12/83	2880	0	597.55	2282.45	0	
9/83 - 1/84	3600	0	597.55	3002.45	0	
9/83 - 2/84	4320	0	597.55	3722.45	0	
9/83 - 3/84	5040	0	597.55	4442.45	0	
9/83 - 4/84	5760	0	597.95	5162.05	0	
9/83 - 5/84	6480	7.00	597.95	5875.05	1	
9/83 - 6/84	7200	20.00	607.62	6572.38	1	

TABLE B-9. SYSTEM AND SENSOR DATA FOR DUBUQUE, IOWA (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	292.16	427.84	0	
9/83 - 10/83	1440	0	404.66	1035.34	0	
9/83 - 11/83	2160	0	404.66	1755.34	0	
9/83 - 12/83	2880	0	404.66	2475.34	0	
9/83 - 1/84	3600	0	404.66	3195.34	0	
9/83 - 2/84	4320	0	404.66	3915.34	0	
9/83 - 3/84	5040	0	404.66	4635.34	0	
9/83 - 4/84	5760	0	404.66	5355.34	0	
9/83 - 5/84	6480	0	406.66	6073.34	0	
9/83 - 6/84	7200	0	408.26	6791.74	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	5.33	0	3594.67	1	
9/83 - 2/84	4320	5.33	0	4314.67	1	
9/83 - 3/84	5040	5.33	0	5034.67	1	
9/83 - 4/84	5760	5.33	0	5754.67	1	
9/83 - 5/84	6480	5.33	0	6474.67	1	
9/83 - 6/84	7200	5.33	0	7194.67	1	

TABLE B-9. SYSTEM AND SENSOR DATA FOR DUBUQUE, IOWA (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	292.16	427.84	0	
9/83 - 10/83	1440	0	404.66	1035.34	0	
9/83 - 11/83	2160	0	404.66	1755.34	0	
9/83 - 12/83	2880	0	404.66	2475.34	0	
9/83 - 1/84	3600	0	404.66	3195.34	0	
9/83 - 2/84	4320	0	404.66	3915.34	0	
9/83 - 3/84	5040	0	404.66	4635.34	0	
9/83 - 4/84	5760	0	404.66	5355.34	0	
9/83 - 5/84	6480	0	406.66	6073.34	0	
9/83 - 6/84	7200	0	408.26	6791.74	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	292.16	427.84	0	
9/83 - 10/83	1440	0	404.66	1035.34	0	
9/83 - 11/83	2160	2.00	404.66	1753.34	2	876.67
9/83 - 12/83	2880	2.00	404.66	2473.34	2	1236.67
9/83 - 1/84	3600	2.00	404.66	3193.34	2	1596.67
9/83 - 2/84	4320	2.00	404.66	3913.34	2	1956.67
9/83 - 3/84	5040	2.00	404.66	4633.34	2	2316.67
9/83 - 4/84	5760	2.00	404.66	5353.34	2	2676.67
9/83 - 5/84	6480	2.00	406.66	6071.34	2	3035.67
9/83 - 6/84	7200	2.00	408.26	6789.74	2	3394.87

TABLE B-9. SYSTEM AND SENSOR DATA FOR DUBUQUE, IOWA (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	292.16	427.84	0	
9/83 - 10/83	1440	0	404.66	1035.34	0	
9/83 - 11/83	2160	0	937.66	1222.34	0	
9/83 - 12/83	2880	0	937.66	1942.34	0	
9/83 - 1/84	3600	0	937.66	2662.34	0	
9/83 - 2/84	4320	3.30	937.66	3379.04	1	
9/83 - 3/84	5040	3.30	937.66	4099.04	1	
9/83 - 4/84	5760	3.30	937.66	4819.04	1	
9/83 - 5/84	6480	3.30	939.66	5537.04	1	
9/83 - 6/84	7200	4.00	941.26	6254.74	1	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	292.16	427.84	0	
9/83 - 10/83	1440	0	404.66	1035.34	0	
9/83 - 11/83	2160	0.50	404.91	1754.59	1	
9/83 - 12/83	2880	0.50	405.08	2474.42	1	
9/83 - 1/84	3600	0.50	405.08	3194.42	1	
9/83 - 2/84	4320	0.50	405.08	3914.42	1	
9/83 - 3/84	5040	0.50	405.08	4634.42	1	
9/83 - 4/84	5760	0.50	405.08	5354.42	1	
9/83 - 5/84	6480	0.50	407.08	6072.42	1	
9/83 - 6/84	7200	0.50	408.68	6790.82	1	

TABLE B-9. SYSTEM AND SENSOR DATA FOR DUBUQUE, IOWA

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	273.16	446.84	7	63.83
9/83 - 10/83	1440	385.58	1054.42	8	131.80
9/83 - 11/83	2160	918.83	1241.17	10	124.11
9/83 - 12/83	2880	919.00	1961.00	11	178.27
9/83 - 1/84	3600	919.00	2681.00	11	243.73
9/83 - 2/84	4320	919.00	3401.00	11	309.18
9/83 - 3/84	5040	919.00	4121.00	11	374.64
9/83 - 4/84	5760	919.00	4841.00	11	440.09
9/83 - 5/84	6480	921.00	5559.00	13	427.62
9/83 - 6/84	7200	922.60	6277.40	14	448.38

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	375.50	292.16	52.34	1	
9/83 - 10/83	1440	694.50	404.66	340.84	2	170.42
9/83 - 11/83	2160	801.50	937.66	420.84	3	140.28
9/83 - 12/83	2880	803.00	937.66	1139.34	4	284.84
9/83 - 1/84	3600	806.00	937.66	1856.34	5	371.27
9/83 - 2/84	4320	806.00	937.66	2576.34	5	515.27
9/83 - 3/84	5040	1358.00	937.66	2744.34	6	457.39
9/83 - 4/84	5760	1829.71	937.66	2992.63	6	498.77
9/83 - 5/84	6480	1829.71	939.66	3710.63	6	618.44
9/83 - 6/84	7200	1829.71	941.26	4429.03	6	738.17

TABLE B-8. SYSTEM AND SENSOR DATA FOR WASHINGTON, D.C. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	0	11.38	2868.62	0	
9/83 - 1/84	3600	0	11.38	3588.62	0	
9/83 - 2/84	4320	104.70	58.88	4156.42	1	
9/83 - 3/84	5040	824.70	58.88	4156.42	1	
9/83 - 4/84	5760	1544.70	58.88	4156.42	1	
9/83 - 5/84	6480	2264.70	58.88	4156.42	1	
9/83 - 6/84	7200	2984.70	58.88	4156.42	1	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0.50	0	1439.50	1	
9/83 - 11/83	2160	0.50	0	2159.50	1	
9/83 - 12/83	2880	0.50	0	2879.50	1	
9/83 - 1/84	3600	0.50	0	3599.50	1	
9/83 - 2/84	4320	0.50	0	4319.50	1	
9/83 - 3/84	5040	0.50	0	5039.50	1	
9/83 - 4/84	5760	0.50	0	5759.50	1	
9/83 - 5/84	6480	0.50	0	6479.50	1	
9/83 - 6/84	7200	0.50	0	7199.50	1	

TABLE B-8. SYSTEM AND SENSOR DATA FOR WASHINGTON, D.C. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	0	11.38	2868.62	0	
9/83 - 1/84	3600	0	11.38	3588.62	0	
9/83 - 2/84	4320	0	58.88	4261.12	0	
9/83 - 3/84	5040	0	58.88	4981.12	0	
9/83 - 4/84	5760	0	58.88	5701.12	0	
9/83 - 5/84	6480	0	58.88	6421.12	0	
9/83 - 6/84	7200	0	58.88	7141.12	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	0	11.38	2868.62	0	
9/83 - 1/84	3600	0	11.38	3588.62	0	
9/83 - 2/84	4320	0	58.88	4261.12	0	
9/83 - 3/84	5040	0	58.88	4981.12	0	
9/83 - 4/84	5760	0	58.88	5701.12	0	
9/83 - 5/84	6480	370.50	58.88	6050.62	1	
9/83 - 6/84	7200	1090.50	58.88	6050.62	1	

TABLE B-8. SYSTEM AND SENSOR DATA FOR WASHINGTON, D.C. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	0	11.38	2868.62	0	
9/83 - 1/84	3600	0	11.38	3588.62	0	
9/83 - 2/84	4320	1.90	58.88	4259.22	0	
9/83 - 3/84	5040	2.30	58.88	4978.82	0	
9/83 - 4/84	5760	2.30	58.88	5698.82	0	
9/83 - 5/84	6480	2.70	58.88	6418.42	0	
9/83 - 6/84	7200	2.70	58.88	7138.42	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	0	11.38	2868.62	0	
9/83 - 1/84	3600	0	11.38	3588.62	0	
9/83 - 2/84	4320	0	58.88	4261.12	0	
9/83 - 3/84	5040	0	58.88	4981.12	0	
9/83 - 4/84	5760	0	58.88	5701.12	0	
9/83 - 5/84	6480	0	58.88	6421.12	0	
9/83 - 6/84	7200	0	58.88	7141.12	0	

TABLE B-8. SYSTEM AND SENSOR DATA FOR WASHINGTON, D.C.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	1.27	718.73	5	143.75
9/83 - 10/83	1440	9.98	1430.02	15	95.33
9/83 - 11/83	2160	11.38	2148.62	17	126.39
9/83 - 12/83	2880	11.38	2868.62	17	168.74
9/83 - 1/84	3600	11.38	3588.62	17	211.10
9/83 - 2/84	4320	58.88	4261.12	18	236.73
9/83 - 3/84	5040	58.88	4981.12	18	276.73
9/83 - 4/84	5760	58.88	5701.12	18	316.73
9/83 - 5/84	6480	58.88	6421.12	18	356.73
9/83 - 6/84	7200	58.88	7141.12	18	396.73

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	1.27	718.73	0	
9/83 - 10/83	1440	0	9.98	1430.02	0	
9/83 - 11/83	2160	0	11.38	2148.62	0	
9/83 - 12/83	2880	343.33	11.38	2525.29	1	
9/83 - 1/84	3600	343.33	11.38	3245.29	1	
9/83 - 2/84	4320	345.23	58.88	3915.89	1	
9/83 - 3/84	5040	345.63	58.58	4635.49	1	
9/83 - 4/84	5760	345.63	58.58	5355.49	1	
9/83 - 5/84	6480	346.03	58.58	6075.09	1	
9/83 - 6/84	7200	346.03	58.88	6795.09	1	

TABLE B-7. SYSTEM AND SENSOR DATA FOR GALENA, ALASKA (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	36.00	684.00	0	
9/83 - 10/83	1440	0	36.00	1404.00	0	
9/83 - 11/83	2160	0	36.00	2124.00	0	
9/83 - 12/83	2880	0	36.00	2844.00	0	
9/83 - 1/84	3600	0	36.00	3564.00	0	
9/83 - 2/84	4320	0	36.00	4284.00	0	
9/83 - 3/84	5040	0	36.00	5004.00	0	
9/83 - 4/84	5760	0	36.00	5724.00	0	
9/83 - 5/84	6480	0	36.00	6444.00	0	
9/83 - 6/84	7200	0	36.00	7164.00	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-7. SYSTEM AND SENSOR DATA FOR GALENA, ALASKA (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	36.00	684.00	0	
9/83 - 10/83	1440	0	36.00	1404.00	0	
9/83 - 11/83	2160	0	36.00	2124.00	0	
9/83 - 12/83	2880	0	36.00	2844.00	0	
9/83 - 1/84	3600	0	36.00	3564.00	0	
9/83 - 2/84	4320	0	36.00	4284.00	0	
9/83 - 3/84	5040	0	36.00	5004.00	0	
9/83 - 4/84	5760	0	36.00	5724.00	0	
9/83 - 5/84	6480	0	36.00	6444.00	0	
9/83 - 6/84	7200	0	36.00	7164.00	0	

F. Dew Point Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	36.00	684.00	0	
9/83 - 10/83	1440	0	36.00	1404.00	0	
9/83 - 11/83	2160	0	36.00	2124.00	0	
9/83 - 12/83	2880	0	36.00	2844.00	0	
9/83 - 1/84	3600	0	36.00	3564.00	0	
9/83 - 2/84	4320	0	36.00	4284.00	0	
9/83 - 3/84	5040	0	36.00	5004.00	0	
9/83 - 4/84	5760	0	36.00	5724.00	0	
9/83 - 5/84	6480	0	36.00	6444.00	0	
9/83 - 6/84	7200	0	36.00	7164.00	0	

TABLE B-7. SYSTEM AND SENSOR DATA FOR GALENA, ALASKA (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	36.00	684.00	0	
9/83 - 10/83	1440	0	36.00	1404.00	0	
9/83 - 11/83	2160	0	36.00	2124.00	0	
9/83 - 12/83	2880	0	36.00	2844.00	0	
9/83 - 1/84	3600	0	36.00	3564.00	0	
9/83 - 2/84	4320	0	36.00	4284.00	0	
9/83 - 3/84	5040	0	36.00	5004.00	0	
9/83 - 4/84	5760	0	36.00	5724.00	0	
9/83 - 5/84	6480	0	36.00	6444.00	0	
9/83 - 6/84	7200	0	36.00	7164.00	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	36.00	684.00	0	
9/83 - 10/83	1440	0	36.00	1404.00	0	
9/83 - 11/83	2160	0	36.00	2124.00	0	
9/83 - 12/83	2880	0	36.00	2844.00	0	
9/83 - 1/84	3600	0	36.00	3564.00	0	
9/83 - 2/84	4320	0	36.00	4284.00	0	
9/83 - 3/84	5040	0	36.00	5004.00	0	
9/83 - 4/84	5760	0	36.00	5724.00	0	
9/83 - 5/84	6480	0	36.00	6444.00	0	
9/83 - 6/84	7200	0	36.00	7164.00	0	

TABLE B-7. SYSTEM AND SENSOR DATA FOR GALENA, ALASKA

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	36.00	684.00	1	
9/83 - 10/83	1440	36.00	1404.00	1	
9/83 - 11/83	2160	36.00	2124.00	1	
9/83 - 12/83	2880	36.00	2844.00	1	
9/83 - 1/84	3600	36.00	3564.00	1	
9/83 - 2/84	4320	36.00	4284.00	1	
9/83 - 3/84	5040	36.00	5004.00	1	
9/83 - 4/84	5760	36.00	5724.00	1	
9/83 - 5/84	6480	36.00	6444.00	1	
9/83 - 6/84	7200	36.00	7164.00	1	

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	360.00	36.00	324.00	1	
9/83 - 10/83	1440	507.00	36.00	897.00	1	
9/83 - 11/83	2160	507.00	36.00	1617.00	1	
9/83 - 12/83	2880	507.00	36.00	2337.00	1	
9/83 - 1/84	3600	507.00	36.00	3057.00	1	
9/83 - 2/84	4320	507.00	36.00	3777.00	1	
9/83 - 3/84	5040	507.00	36.00	4497.00	1	
9/83 - 4/84	5760	507.00	36.00	5217.00	1	
9/83 - 5/84	6480	507.00	36.00	5937.00	1	
9/83 - 6/84	7200	507.00	36.00	6657.00	1	

TABLE B-10. SYSTEM AND SENSOR DATA FOR HOUMA, LA. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	313.35	406.65	0	
9/83 - 10/83	1440	0	463.52	976.48	0	
9/83 - 11/83	2160	0	597.55	1562.45	0	
9/83 - 12/83	2880	0	597.55	2282.45	0	
9/83 - 1/84	3600	0	597.55	3002.45	0	
9/83 - 2/84	4320	0	597.55	3722.45	0	
9/83 - 3/84	5040	0	597.55	4442.45	0	
9/83 - 4/84	5760	0	597.55	5162.45	0	
9/83 - 5/84	6480	0	597.55	5882.45	0	
9/83 - 6/84	7200	0	607.22	6592.78	0	

F. Dewpoint Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	313.35	406.65	0	
9/83 - 10/83	1440	0	463.52	976.48	0	
9/83 - 11/83	2160	0	597.55	1562.45	0	
9/83 - 12/83	2880	51.50	597.55	2230.95	2	1115.48
9/83 - 1/84	3600	51.50	597.55	2950.95	2	1475.48
9/83 - 2/84	4320	246.40	597.55	3476.05	4	869.01
9/83 - 3/84	5040	293.40	597.55	4149.05	4	1037.26
9/83 - 4/84	5760	293.40	597.55	4869.05	4	1217.26
9/83 - 5/84	6480	293.40	597.55	5589.05	4	1397.26
9/83 - 6/84	7200	293.40	607.22	6299.38	4	1574.85

TABLE B-10. SYSTEM AND SENSOR DATA FOR HOUMA, LA. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	313.35	406.65	0	
9/83 - 10/83	1440	0	463.52	976.48	0	
9/83 - 11/83	2160	0	597.55	1562.45	0	
9/83 - 12/83	2880	0	597.55	2282.45	0	
9/83 - 1/84	3600	0	597.55	3002.45	0	
9/83 - 2/84	4320	0	597.55	3722.45	0	
9/83 - 3/84	5040	22.70	597.55	4419.75	2	2209.88
9/83 - 4/84	5760	22.70	597.55	5139.75	2	2569.88
9/83 - 5/84	6480	22.70	597.55	5859.75	2	2929.88
9/83 - 6/84	7200	22.70	607.22	6570.08	2	3285.04

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	3.80	4316.20	0	
9/83 - 3/84	5040	0	3.80	5036.20	0	
9/83 - 4/84	5760	0	3.80	5756.20	0	
9/83 - 5/84	6480	0	3.80	6476.20	0	
9/83 - 6/84	7200	0	13.47	7186.53	0	

TABLE B-11. SYSTEM AND SENSOR DATA FOR HOUGHTON, MICH.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	57.39	662.61	23	28.81
9/83 - 10/83	1440	140.12	1299.88	30	43.33
9/83 - 11/83	2160	195.30	1964.70	41	47.92
9/83 - 12/83	2880	198.63	2681.37	48	55.86
9/83 - 1/84	3600	198.63	3401.37	48	70.86
9/83 - 2/84	4320	198.63	4121.37	48	85.86
9/83 - 3/84	5040	198.63	4841.37	48	100.86
9/83 - 4/84	5760	198.63	5561.37	48	115.86
9/83 - 5/84	6480	198.63	6281.37	48	130.86
9/83 - 6/84	7200	198.63	7001.37	48	145.86

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	53.30	667.00	0	
9/83 - 10/83	1440	0	136.28	1303.72	0	
9/83 - 11/83	2160	0	191.46	1968.54	0	
9/83 - 12/83	2880	650.00	194.76	2035.24	1	
9/83 - 1/84	3600	650.00	194.76	2755.24	1	
9/83 - 2/84	4320	650.00	194.76	3475.24	1	
9/83 - 3/84	5040	650.00	194.76	4195.24	1	
9/83 - 4/84	5760	650.00	194.76	4915.24	1	
9/83 - 5/84	6480	650.00	194.76	5635.24	1	
9/83 - 6/84	7200	650.00	194.76	6355.24	1	

TABLE B-11. SYSTEM AND SENSOR DATA FOR HOUGHTON, MICH. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	53.55	666.45	0	
9/83 - 10/83	1440	0	136.53	1303.47	0	
9/83 - 11/83	2160	0	191.71	1968.29	0	
9/83 - 12/83	2880	0	195.01	2684.99	0	
9/83 - 1/84	3600	0	195.01	3404.99	0	
9/83 - 2/84	4320	0	195.01	4124.99	0	
9/83 - 3/84	5040	0	195.01	4844.99	0	
9/83 - 4/84	5760	0	195.01	5564.99	0	
9/83 - 5/84	6480	0	195.01	6284.99	0	
9/83 - 6/84	7200	0	195.01	7004.99	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	56.52	663.48	0	
9/83 - 10/83	1440	0	139.50	1300.50	0	
9/83 - 11/83	2160	0	194.68	1965.32	0	
9/83 - 12/83	2880	24.00	197.98	2658.02	1	
9/83 - 1/84	3600	24.00	197.98	3378.02	1	
9/83 - 2/84	4320	24.00	197.98	4098.02	1	
9/83 - 3/84	5040	24.00	197.98	4818.02	1	
9/83 - 4/84	5760	24.00	197.98	5538.02	1	
9/83 - 5/84	6480	24.00	197.98	6258.02	1	
9/83 - 6/84	7200	24.00	197.98	6978.02	1	

TABLE B-11. SYSTEM AND SENSOR DATA FOR HOUGHTON, MICH. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	53.30	666.70	0	
9/83 - 10/83	1440	0	136.28	1303.72	0	
9/83 - 11/83	2160	0	191.46	1968.54	0	
9/83 - 12/83	2880	0	194.76	2685.24	0	
9/83 - 1/84	3600	0	194.76	3405.24	0	
9/83 - 2/84	4320	0	194.76	4125.24	0	
9/83 - 3/84	5040	0	194.76	4845.24	0	
9/83 - 4/84	5760	0	194.76	5565.24	0	
9/83 - 5/84	6480	0	194.76	6285.24	0	
9/83 - 6/84	7200	0	194.76	7005.24	0	

F. Dewpoint Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	53.92	666.08	0	
9/83 - 10/83	1440	0	136.90	1303.10	0	
9/83 - 11/83	2160	0	192.08	1967.92	0	
9/83 - 12/83	2880	0	195.38	2684.62	0	
9/83 - 1/84	3600	0	195.38	3404.62	0	
9/83 - 2/84	4320	48.17	195.38	4076.45	1	
9/83 - 3/84	5040	48.17	195.38	4796.45	1	
9/83 - 4/84	5760	48.17	195.38	5516.45	1	
9/83 - 5/84	6480	48.17	195.38	6236.45	1	
9/83 - 6/84	7200	48.17	195.38	6956.45	1	

TABLE B-11. SYSTEM AND SENSOR DATA FOR HOUGHTON, MICH. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	720.00	0	0	1	
9/83 - 10/83	1440	1440.00	0	0	1	
9/83 - 11/83	2160	2160.00	0	0	1	
9/83 - 12/83	2880	2880.00	0	0	1	
9/83 - 1/84	3600	3600.00	0	0	1	
9/83 - 2/84	4320	4320.00	0	0	1	
9/83 - 3/84	5040	4920.00	0	120.00	1	
9/83 - 4/84	5760	4920.00	0	840.00	1	
9/83 - 5/84	6480	5640.00	0	840.00	2	420.00
9/83 - 6/84	7200	6360.00	0	840.00	2	420.00

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0.30	0	2159.70	1	
9/83 - 12/83	2880	0.30	0	2879.70	1	
9/83 - 1/84	3600	0.30	0	3599.70	1	
9/83 - 2/84	4320	0.30	0	4319.70	1	
9/83 - 3/84	5040	0.30	0	5039.70	1	
9/83 - 4/84	5760	0.30	0	5759.70	1	
9/83 - 5/84	6480	0.30	0	6479.70	1	
9/83 - 6/84	7200	0.30	0	7199.70	1	

TABLE B-12. SYSTEM AND SENSOR DATA FOR BREMERTON, WASH.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	15.73	704.27	8	88.03
9/83 - 10/83	1440	34.11	1405.89	15	93.73
9/83 - 11/83	2160	86.28	2073.72	25	82.95
9/83 - 12/83	2880	86.33	2793.67	26	107.45
9/83 - 1/84	3600	340.58	3259.42	27	120.72
9/83 - 2/84	4320	411.08	3908.92	30	130.30
9/83 - 3/84	5040	415.83	4624.17	31	149.17
9/83 - 4/84	5760	416.08	5343.92	35	152.68
9/83 - 5/84	6480	457.48	6022.52	38	158.49
9/83 - 6/84	7200	469.98	6730.02	39	172.56

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	11.40	708.60	0	
9/83 - 10/83	1440	0	23.78	1416.22	0	
9/83 - 11/83	2160	0	31.78	2128.22	0	
9/83 - 12/83	2880	156.00	31.83	2692.17	1	
9/83 - 1/84	3600	156.00	286.08	3157.92	1	
9/83 - 2/84	4320	156.00	356.58	3807.42	1	
9/83 - 3/84	5040	156.00	361.33	4522.67	1	
9/83 - 4/84	5760	156.00	361.58	5242.42	1	
9/83 - 5/84	6480	156.00	402.98	5921.02	1	
9/83 - 6/84	7200	156.00	415.48	6628.52	1	

TABLE B-12. SYSTEM AND SENSOR DATA FOR BREMERTON, WASH. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	11.40	708.60	0	
9/83 - 10/83	1440	0	23.78	1416.22	0	
9/83 - 11/83	2160	0	31.78	2128.22	0	
9/83 - 12/83	2880	0	31.83	2848.17	0	
9/83 - 1/84	3600	0	286.08	3313.92	0	
9/83 - 2/84	4320	0	356.58	3963.42	0	
9/83 - 3/84	5040	0	361.33	4678.67	0	
9/83 - 4/84	5760	0.43	361.58	5397.99	1	
9/83 - 5/84	6480	0.43	402.98	6076.59	1	
9/83 - 6/84	7200	0.43	415.48	6784.09	1	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	15.65	704.35	0	
9/83 - 10/83	1440	0	28.03	1411.97	0	
9/83 - 11/83	2160	0	36.03	2123.97	0	
9/83 - 12/83	2880	0	36.08	2843.92	0	
9/83 - 1/84	3600	0	290.33	3309.67	0	
9/83 - 2/84	4320	0	360.83	3959.17	0	
9/83 - 3/84	5040	0	365.58	4674.42	0	
9/83 - 4/84	5760	0	365.83	5394.17	0	
9/83 - 5/84	6480	0	407.23	6072.77	0	
9/83 - 6/84	7200	0	419.73	6780.27	0	

TABLE B-12. SYSTEM AND SENSOR DATA FOR BREMERTON, WASH. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	11.40	708.60	0	
9/83 - 10/83	1440	0	23.78	1416.22	0	
9/83 - 11/83	2160	0	31.78	2128.22	0	
9/83 - 12/83	2880	0	31.83	2848.17	0	
9/83 - 1/84	3600	0	286.08	3313.92	0	
9/83 - 2/84	4320	0	356.58	3963.42	0	
9/83 - 3/84	5040	0	361.33	4678.67	0	
9/83 - 4/84	5760	0	361.58	5398.42	0	
9/83 - 5/84	6480	0	402.98	6077.02	0	
9/83 - 6/84	7200	0	415.48	6784.52	0	

F. Dewpoint Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	11.48	708.52	0	
9/83 - 10/83	1440	0	29.86	1410.14	0	
9/83 - 11/83	2160	0	82.03	2077.97	0	
9/83 - 12/83	2880	0	82.08	2797.92	0	
9/83 - 1/84	3600	0	336.33	3263.67	0	
9/83 - 2/84	4320	0	406.83	3913.17	0	
9/83 - 3/84	5040	2.00	411.58	4626.42	1	
9/83 - 4/84	5760	2.00	411.83	5346.17	1	
9/83 - 5/84	6480	2.00	453.23	6024.77	1	
9/83 - 6/84	7200	2.00	465.73	6732.27	1	

TABLE B-12. SYSTEM AND SENSOR DATA FOR BREMERTON, WASH. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	11.40	708.60	0	
9/83 - 10/83	1440	0	23.78	1416.22	0	
9/83 - 11/83	2160	0	31.78	2128.22	0	
9/83 - 12/83	2880	0	31.83	2848.17	0	
9/83 - 1/84	3600	0	286.08	3313.92	0	
9/83 - 2/84	4320	0	356.58	3963.42	0	
9/83 - 3/84	5040	0	361.33	4678.67	0	
9/83 - 4/84	5760	0	361.58	5398.42	0	
9/83 - 5/84	6480	0	402.98	6077.02	0	
9/83 - 6/84	7200	0	415.48	6784.52	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE B-13. SYSTEM AND SENSOR DATA FOR SANTA FE, N. MEX.

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	720.00	0	
9/83 - 10/83	1440	0.70	1439.30	2	719.65
9/83 - 11/83	2160	0.95	2159.05	4	539.76
9/83 - 12/83	2880	0.95	2879.05	4	719.76
9/83 - 1/84	3600	43.78	3556.22	5	711.24
9/83 - 2/84	4320	43.78	4276.22	5	855.24
9/83 - 3/84	5040	43.78	4996.22	5	999.24
9/83 - 4/84	5760	43.78	5716.22	5	1143.24
9/83 - 5/84	6480	43.78	6436.22	5	1287.24
9/83 - 6/84	7200	43.78	7156.22	5	1431.24

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0.08	2159.92	0	
9/83 - 12/83	2880	0	0.08	2879.92	0	
9/83 - 1/84	3600	0	42.91	3557.09	0	
9/83 - 2/84	4320	0	42.91	4277.09	0	
9/83 - 3/84	5040	0	42.91	4997.09	0	
9/83 - 4/84	5760	0	42.91	5717.09	0	
9/83 - 5/84	6480	0	42.91	6437.09	0	
9/83 - 6/84	7200	0	42.91	7157.09	0	

TABLE B-13. SYSTEM AND SENSOR DATA FOR SANTA FE, N. MEX. (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0.08	2159.92	0	
9/83 - 12/83	2880	0	0.08	2879.92	0	
9/83 - 1/84	3600	0	42.91	3557.09	0	
9/83 - 2/84	4320	0	42.91	4277.09	0	
9/83 - 3/84	5040	0	42.91	4997.09	0	
9/83 - 4/84	5760	0	42.91	5717.09	0	
9/83 - 5/84	6480	0	42.91	6437.09	0	
9/83 - 6/84	7200	0	42.91	7157.09	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0.20	1439.80	0	
9/83 - 11/83	2160	0	0.28	2159.72	0	
9/83 - 12/83	2880	0	0.28	2879.72	0	
9/83 - 1/84	3600	0	0.28	3599.72	0	
9/83 - 2/84	4320	0	0.28	4319.72	0	
9/83 - 3/84	5040	0	0.28	5039.72	0	
9/83 - 4/84	5760	0	0.28	5759.72	0	
9/83 - 5/84	6480	0	0.28	6479.72	0	
9/83 - 6/84	7200	0	0.28	7199.72	0	

TABLE B-13. SYSTEM AND SENSOR DATA FOR SANTA FE, N. MEX. (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	26.50	0	1413.50	1	
9/83 - 11/83	2160	26.50	0.25	2133.25	1	
9/83 - 12/83	2880	26.50	0.25	2853.25	1	
9/83 - 1/84	3600	26.50	0.25	3573.25	1	
9/83 - 2/84	4320	26.50	0.25	4293.25	1	
9/83 - 3/84	5040	26.50	0.25	5013.25	1	
9/83 - 4/84	5760	26.50	0.25	5733.25	1	
9/83 - 5/84	6480	26.50	0.25	6453.25	1	
9/83 - 6/84	7200	26.50	0.25	7173.25	1	

F. Dewpoint Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0.50	1439.50	0	
9/83 - 11/83	2160	0	0.75	2159.25	0	
9/83 - 12/83	2880	0	0.75	2879.25	0	
9/83 - 1/84	3600	0	0.75	3599.25	0	
9/83 - 2/84	4320	0	0.75	4319.25	0	
9/83 - 3/84	5040	0	0.75	5039.25	0	
9/83 - 4/84	5760	0	0.75	5759.25	0	
9/83 - 5/84	6480	0	0.75	6479.25	0	
9/83 - 6/84	7200	0	0.75	7199.25	0	

TABLE B-13. SYSTEM AND SENSOR DATA FOR SANTA FE, N. MEX. (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0.08	2159.92	0	
9/83 - 12/83	2880	0	0.08	2879.92	0	
9/83 - 1/84	3600	0	0.08	3599.92	0	
9/83 - 2/84	4320	0	0.08	4319.92	0	
9/83 - 3/84	5040	0	0.08	5039.92	0	
9/83 - 4/84	5760	0	0.08	5759.92	0	
9/83 - 5/84	6480	0	0.08	6479.92	0	
9/83 - 6/84	7200	0	0.08	7199.92	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	0	3600.00	0	
9/83 - 2/84	4320	0	0	4320.00	0	
9/83 - 3/84	5040	0	0	5040.00	0	
9/83 - 4/84	5760	0	0	5760.00	0	
9/83 - 5/84	6480	0	0	6480.00	0	
9/83 - 6/84	7200	0	0	7200.00	0	

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Ceiling	DCA	1	12/83		Ceil out of service/replaced ceil processor board
	HUM	1	5/84	6/84	Always miss at 1801Z/unresolved
	DBQ	1	9/83	9/83	Ceilograph failure/sensor out of alignment
		2	10/83	10/83	Sky miss/replaced 807 board in ceilograph
		3	11/83	11/83	Sky intermittent/replaced 807 board in ceilograph
		4	12/83	12/83	Ceiling incorrect/reset ceilometer by cycling power
		5	1/84	1/84	Sky missing/adjust sensor
		6	3/84	4/84	Ceilometer failure/replaced power diode
	CMX	1	11/83	12/83	Sensor gets stuck on 'M60VC'/replaced receiver boards
	PWT	1	11/83	12/83	Reading miss dusk to dawn/replace bad optical coupler
	SAF	None			
	VDZ	1	9/83	10/83	CHI out of service/adjusted sensor
Visibility	DCA	None			
	HUM	1	11/83	11/83	Low readings due to cobwebs on sensor/removed
		2	12/83	12/83	Low readings due to cobwebs on sensor/removed
		3	12/83	12/83	Low readings due to cobwebs on sensor/removed
		4	12/83	12/83	Low readings due to cobwebs on sensor/removed
		5	12/83	12/83	Low readings due to cobwebs on sensor/removed
		6	2/84	2/84	Low readings due to cobwebs on sensor/removed
	DBQ	1	2/84	2/84	Reading incorrect/replaced defective module
	CMX	None			
	PWT	1	4/84	4/84	Visibility not reported/reset main power breaker on transmitter
	SAF	None			
	VDZ	None			
Wind	DCA	None			
	HUM	None			
	DBQ	1	11/83	11/83	Wind speed miss/hardware reset
	CMX	1	12/83	12/83	Wind dir miss/lowered voltage to correct problem

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
System	PWT	7	9/83	9/83	FDC comm error/reset FDC
		8	9/83	9/83	FDC comm error/reset FDC
		9	10/83	10/83	FDC comm error/reset FDC
		10	10/83	10/83	FDC comm error/reset FDC
		11	10/83	10/83	FDC comm error/reset FDC
		12	10/83	10/83	FDC comm error/reset FDC
		13	10/83	10/83	Sys inoperable, no phone call-up/reset FDC
		14	10/83	10/83	Sys inoperable, except pressure reports/ reset FDC
		15	10/83	10/83	Dewpoint miss/reset FDC
		16	11/83	11/83	Sys inoperable/reset FDC
		17	11/83	11/83	Sys inoperable/reset FDC
		18	11/83	11/83	Sys inoperable/reset FDC
		19	11/83	11/83	Only alt reading/reset fiber optic modem (power failure)
		20	11/83	11/83	Dewpoint reported miss/reset FDC
		21	11/83	11/83	Dewpoint reported miss/reset FDC
		22	11/83	11/83	Only reporting alt/reset FDC
		23	11/83	11/83	Sys inoperable/reset fiber optic modem (power failure)
		24	11/83	11/83	FDC error/reset fiber optic modem (no power failure)
		25	11/83	11/83	Dewpoint miss/reset FDC
		26	12/83	12/83	FDC comm error/reset fiber optic modem
		27	1/84	2/84	Fiber optic com link between FDC & CPU/repair
		28	2/84	2/84	FDC comm error/resolder points in FDC board
		29	2/84	2/84	FDC comm error/reset FDC
		30	2/84	2/84	FDC comm error/reset FDC
		31	3/84	3/84	FDC comm error/reset FDC
		32	4/84	4/84	FDC comm error/reset fiber optic modem
		33	4/84	4/84	FDC comm error/reset fiber optic modem
		34	4/84	4/84	FDC comm error/reset fiber optic modem
		35	4/84	4/84	FDC comm error/reset fiber optic modem
		36	5/84	5/84	FDC comm error/reset fiber optic modem
		37	5/84	5/84	FDC comm error/reset fiber optic modem
		38	5/84	5/84	CPU hang up/reset CPU
		39	6/84	6/84	Ceiling & vis out/reset FDC
	SAF	1	10/83	10/83	Wind speed miss/reset CPU
		2	10/83	10/83	Dewpoint miss/reset CPU
		3	11/83	11/83	Dewpoint & temp miss/reset CPU
		4	11/83	11/83	CPU hung-up/reset system CPU
		5	1/84	1/84	Vis & ceilometer problem/realigned tasker
	VDZ	1	9/83	9/83	Temp, dewpoint, wind speed, wind direction out FDC comm error/reset FDC
		2	10/83	10/83	CPU hang-up/reset CPU
		3	10/83	10/83	CPU hang-up/reset CPU
		4	10/83	10/83	CPU hang-up/reset CPU
		5	10/83	10/83	CPU hang-up/reset CPU
		6	12/83	1/84	FDC failure/replaced board in FDC

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
System	CMX	8	9/83	9/83	FDC comm error/FDC software reset
		9	9/83	9/83	FDC comm error/FDC software reset
		10	9/83	9/83	FDC comm error/FDC hardware reset
		11	9/83	9/83	FDC comm error/reset FDC
		12	9/83	9/83	FDC comm error/FDC hardware reset
		13	9/83	9/83	FDC comm error/FDC software reset
		14	9/83	9/83	FDC comm error/reset FDC
		15	9/83	9/83	FDC comm error/reset FDC
		16	9/83	9/83	FDC comm error/reset FDC
		17	9/83	9/83	FDC comm error/FDC software reset
		18	9/83	9/83	FDC comm error/FDC software reset
		19	9/83	9/83	FDC comm error/reset FDC
		20	9/83	9/83	FDC comm error/reset FDC
		21	9/83	9/83	FDC comm error/reset FDC
		22	9/83	9/83	FDC comm error/reset FDC
		23	9/83	9/83	FDC comm error/FDC software reset
		24	10/83	10/83	FDC comm error/FDC hardware reset
		25	10/83	10/83	FDC comm error/reset FDC
		26	10/83	10/83	FDC comm error/reset FDC
		27	10/83	10/83	FDC comm error/reset FDC
		28	10/83	10/83	FDC comm error/reset FDC
		29	10/83	10/83	FDC comm error/reset FDC
		30	10/83	10/83	FDC comm error/reset FDC
		31	11/83	11/83	FDC comm error/reset FDC
		32	11/83	11/83	FDC comm error/reset FDC
		33	11/83	11/83	FDC comm error/reset FDC
		34	11/83	11/83	FDC comm error/reset FDC
		35	11/83	11/83	FDC comm error/reset FDC
		36	11/83	11/83	FDC comm error/reset FDC
		37	11/83	11/83	FDC comm error/reset FDC
		38	11/83	11/83	FDC comm error/reset FDC
		39	11/83	11/83	FDC comm error/reset FDC
		40	11/83	11/83	FDC comm error/reset FDC
		41	11/83	11/83	FDC comm error/reset FDC
		42	12/83	12/83	FDC comm error/reset FDC
		43	12/83	12/83	FDC comm error/reset FDC
		44	12/83	12/83	FDC comm error/reset FDC
		45	12/83	12/83	FDC comm error/reset FDC
		46	12/83	12/83	FDC comm error/reset FDC
		47	12/83	12/83	FDC comm error/reset FDC
		48	12/83	12/83	FDC comm error/reset FDC
	PWT	1	9/83	9/83	FDC comm error/reset FDC
		2	9/83	9/83	FDC comm error/reset FDC
		3	9/83	9/83	FDC comm error/reset FDC
		4	9/83	9/83	FDC comm error/reset FDC
		5	9/83	9/83	FDC comm error/reset FDC
		6	9/83	9/83	FDC comm error/reset FDC

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
System	HUM	30	11/83	11/83	CPU hung-up/reset system CPU
		31	11/83	11/83	CPU hung-up/reset system CPU
		32	11/83	11/83	CPU hung-up/reset system CPU
		33	11/83	11/83	CPU hung-up/reset system CPU
		34	11/83	11/83	CPU hung-up/reset system CPU
		35	11/83	11/83	CPU hung-up/reset system CPU
		36	11/83	11/83	CPU hung-up/reset system CPU
		37	11/83	11/83	CPU hung-up/reset system CPU
		38	11/83	11/83	CPU hung-up/reset system CPU
		39	11/83	11/83	CPU hung-up/reset system CPU
		40	11/83	11/83	CPU hung-up/reset system CPU
		41	11/83	11/83	CPU hung-up/reset system CPU
		42	11/83	11/83	CPU hung-up/reset system CPU
		43	11/83	11/83	CPU hung-up/reset system CPU
		44	11/83	11/83	CPU hung-up/reset system CPU
		45	11/83	11/83	CPU hung-up/reset system CPU
		46	11/83	11/83	CPU hung-up/reset system CPU
		47	11/83	11/83	CPU hung-up/reset system CPU
		48	11/83	11/83	CPU hung-up/reset system CPU
		49	11/83	11/83	CPU hung-up/reset system CPU
		50	11/83	11/83	CPU hung-up/reset system CPU
		51	2/84	2/84	Altimeter miss/reset CPU
		52	4/84	4/84	Cloud height & vis error/cleaned vis & ceilo sensor
		53	4/84	4/84	Cloud height & vis error/cleaned vis & ceilo sensor
		54	6/84	6/84	CPU hung-up/reset system CPU
	DBQ	1	9/83	9/83	Telco voice weak/loose components
		2	9/83	9/83	Terminal locked-up/reset system CPU
		3	9/83	9/83	Telco always busy/reset system CPU
		4	9/83	9/83	Telco always busy/reset system CPU
		5	9/83	9/83	Terminal lock up & telco busy/reset system CPU
		6	9/83	9/83	Terminal lock up & no readings except alt/reset FDC
		7	9/83	10/83	Faulty weather processor boards/replace
		8	10/83	10/83	FDC comm error/FDC hardware reset
		9	11/83	11/83	Visibility & ceiling miss/PC board replaced
		10	11/83	11/83	Wind speed miss/reset FDC
		11	12/83	12/83	Wind dir miss/reset FDC
		12	5/84	5/84	FDC comm error/FDC reset
		13	5/84	5/84	FDC comm error/FDC reset
		14	6/84	6/84	Terminal locked-up/reset system CPU via power off
	CMX	1	9/83	9/83	Dewpoint miss/reset FDC
		2	9/83	9/83	FDC comm error/reset FDC
		3	9/83	9/83	Wind speed out of spec/FDC hardware reset
		4	9/83	9/83	FDC comm error/FDC reset
		5	9/83	9/83	FDC comm error/FDC software reset
		6	9/83	9/83	FDC comm error/FDC hardware reset
		7	9/83	9/83	FDC comm error/reset FDC

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
System	DCA	1	9/83	9/83	FDC error/FDC software reset
		2	9/83	9/83	FDC error/FDC software reset
		3	9/83	9/83	FDC error/FDC software reset
		4	9/83	9/83	FDC error/FDC software reset
		5	9/83	9/83	FDC error/FDC software reset
		6	10/83	10/83	FDC error/FDC hardware reset
		7	10/83	10/83	FDC error/FDC hardware reset
		8	10/83	10/83	FDC error/FDC hardware reset
		9	10/83	10/83	FDC error/FDC hardware reset
		10	10/83	10/83	FDC error/FDC hardware reset
		11	10/83	10/83	FDC error/FDC hardware reset
		12	10/83	10/83	FDC error/FDC hardware reset
		13	10/83	10/83	Main CPU hung-up/reset main CPU
		14	10/83	10/83	Main CPU hung-up/reset main CPU
		15	10/83	10/83	Main CPU hung-up/reset main CPU
		16	11/83	11/83	Date/time incorrect/reset manually
		17	11/83	11/83	FDC error/FDC hardware reset
		18	2/84	2/84	Broken switch on board in CPU/replace
	HUM	1	9/83	9/83	Wind direction miss/CPU fault/reset
		2	9/83	9/83	Wind direction miss/CPU fault/reset
		3	9/83	9/83	CPU hung-up/reset system CPU
		4	9/83	9/83	Altitude density missing/CPU fault/reset
		5	9/83	9/83	Voice-phone hangs-up/PROM board revised
		6	9/83	9/83	CPU hung-up/reset system CPU
		7	9/83	9/83	CPU hung-up/reset system CPU
		8	9/83	9/83	CPU hung-up/reset system CPU
		9	9/83	9/83	CPU hung-up/reset system CPU
		10	9/83	9/83	CPU hung-up/reset system CPU
		11	9/83	9/83	CPU hung-up/reset system CPU
		12	10/83	10/83	CPU hung-up/reset system CPU
		13	10/83	10/83	CPU hung-up/reset system CPU
		14	10/83	10/83	CPU hung-up/reset system CPU
		15	10/83	10/83	CPU hung-up/reset system CPU
		16	10/83	10/83	CPU hung-up/reset system CPU
		17	10/83	10/83	CPU hung-up/reset system CPU
		18	10/83	10/83	CPU hung-up/reset system CPU
		19	10/83	10/83	CPU hung-up/reset system CPU
		20	10/83	10/83	CPU hung-up/reset system CPU
		21	10/83	10/83	CPU hung-up/reset system CPU
		22	10/83	10/83	CPU hung-up/reset system CPU
		23	10/83	10/83	CPU hung-up/reset system CPU
		24	10/83	10/83	CPU hung-up/reset system CPU
		25	10/83	10/83	CPU hung-up/reset system CPU
		26	10/83	10/83	CPU hung-up/reset system CPU
		27	10/83	10/83	CPU hung-up/reset system CPU
		28	10/83	10/83	CPU hung-up/reset system CPU
		29	11/83	11/83	CPU hung-up/reset system CPU

TABLE C-1. HISTORICAL ACCOUNT OF WEATHERMEASURE SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

WeatherMeasure	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Altimeter	AUO	None			
	HOU	1	6/84	6/84	S-12 board in rack #2 out of service/replace
	EEN	1	11/83	11/83	Alt missing-both sensor outputs differ/ replace them
		2	1/84	1/84	Alt report too high/adjusted switches on program card
	MIE	None			
	PSP	None			
	SBP	None			
	GAL	None			

TABLE C-1. HISTORICAL ACCOUNT OF WEATHERMEASURE SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

WeatherMeasure	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Temperature	AUO	None			
	HOU	None			
	EEN	None			
	MIE	1	5/84	5/84	Sensor erratic/fixed loose connection to aspirator box
		2	5/84	5/84	Sensor erratic/fixed bad connection on terminal board
	PSP	None			
	SBP	None			
	GAL	None			
Dew Point	AUO	None			
	HOU	None			
	EEN	None			
	MIE	1	12/83	12/83	Dewpoint error/replaced program module
	PSP	None			
	SBP	None			
	GAL	None			
Precipitation	AUO	None			
	HOU	1	9/83	9/83	Precipsensor problem/moisture short + 12V to chassis
	EEN	1	11/83	11/83	No precip report/reset rack #1
		2	1/84	1/84	False precip report, rain gauge full of snow/ adjusted plugs to funnel-cone heater
	MIE	1	10/83	10/83	Bucket not measuring rain/spider webs stopping bucket movement
		2	12/83	12/83	Marginal performance/sensor frozen, funnel heater failure, replaced
	PSP	None			
	SBP	None			
	GAL	None			

TABLE C-1. HISTORICAL ACCOUNT OF WEATHERMEASURE SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

WeatherMeasure	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Visibility	AUO	None			
	HOU	None			
	EEN	1	9/83	9/83	Visibility from backscatter miss/software reset on rack #3
		2	9/83	9/83	Visibility from backscatter miss/software reset on rack #2 & 3
		3	9/83	9/83	Visibility from backscatter miss/software reset on rack #3
		4	9/83	9/83	Visibility report miss(code A)/ reset on rack #2 & 3
		5	9/83	9/83	Visibility report miss(code A)/ reset on rack #3
		6	9/83	9/83	Visibility report miss/reset rack #3
		7	10/83	10/83	Visibility report miss/reset rack #3
		8	10/83	10/83	Visibility report miss/reset rack #3
		9	11/83	11/83	Visibility report miss/reset rack #3
		10	11/83	11/83	Visibility report miss/reset rack #3
		11	11/83	11/83	Visibility report miss/reset rack #3
		12	12/83	12/83	Backscatter sensor saturates/added limiter & recalibrate sig conv board
	MIE	None			
	PSP	1	11/83	11/83	Visibility not stable/replaced detector assembly
	SBP	1	11/83	11/83	Visibility miss/adjusted transmissometer
		2	11/83	11/83	Visibility miss/reset rack #3
		3	12/83	12/83	Visibility missing/sensor correct (self corrected)
	GAL	None			
Wind	AUO	None			
	HOU	1	11/83	11/83	Wind direction 100°-180° off/water in skyvane, replaced part
	EEN	None			
	MIE	None			
	PSP	None			
	SBP	None			
	GAL	None			

TABLE C-1. HISTORICAL ACCOUNT OF WEATHERMEASURE SYSTEM AND SENSOR FAILURES BY SITE

WeatherMeasure	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
System	AUO	1	9/83	9/83	No info from met rack/replaced defective S-12 module
		2	10/83	10/83	Wx info missing from IOT screen/reset CPU
		3	12/83	12/83	Visibility miss/reset racks
		4	3/84	3/84	Visibility miss/replaced S-12 board module
		5	6/84	6/84	Ceiling, temp, dew pt missing/reset CPU
	HOU	1	1/84	1/84	Barometric press miss/replaced S-12 board module
	EEN	1	10/83	10/83	Visibility & wind miss/reset racks
		2	10/83	10/83	Temp, dew pt, wind errors/replaced 12V power supply in (M733 NP) CPU
		3	11/83	11/83	Temp, wind miss & dew pt error/replaced S-12 board module
	MIE	1	9/83	9/83	Met 'J' box power failure/replaced fuse
	PSP	1	11/83	11/83	No reports from met rack #1/defective module replaced
		2	11/83	11/83	Ceiling & visibility errors/cleaned lens & glass windows
	SBP	1	9/83	9/83	Wind, temp, dew pt miss/replaced faulty S-12 board in met box
		2	10/83	10/83	Ceiling & visibility miss/defective S-12 module
		3	10/83	10/83	No met box info/replaced S-12 module
	GAL	1	9/83	9/83	CPU hung-up/reset
Ceiling	AUO	None			
	HOU	1	10/83	10/83	Sunshutter wire broken/replaced it
		2	4/84	5/84	Ceilometer sensor out/replaced SCR
	EEN	1	9/83	9/83	Ceilometer error/increased HDC level from 10 to 12
		2	11/83	11/83	Ceilometer error/decreased HDC level
	MIE	1	10/83	10/83	Ceilometer error/reset rack #3
		2	11/83	11/83	Ceilometer error/continuous till 6/84, unresolved
	PSP	1	5/83	5/83	Ceilometer error/cleaned windows
	SBP	None			
	GAL	1	9/83	10/83	Ceilometer sensor out/defective board module

APPENDIX C

AUTOMATED WEATHER OBSERVING SYSTEM DEMONSTRATION PROGRAM

FAILURE DIAGNOSIS SUMMARY

TABLE B-14. SYSTEM AND SENSOR DATA FOR VALDEZ, ALASKA (CONTINUED)

G. Precipitation Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	145.00	1295.00	0	
9/83 - 11/83	2160	0	145.00	2015.00	0	
9/83 - 12/83	2880	0	457.00	2423.00	0	
9/83 - 1/84	3600	0	865.00	2735.00	0	
9/83 - 2/84	4320	0	865.00	3455.00	0	
9/83 - 3/84	5040	0	865.00	4175.00	0	
9/83 - 4/84	5760	0	865.00	4895.00	0	
9/83 - 5/84	6480	0	865.00	5615.00	0	
9/83 - 6/84	7200	0	865.00	6335.00	0	

H. Altimeter Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	0	1440.00	0	
9/83 - 11/83	2160	0	0	2160.00	0	
9/83 - 12/83	2880	0	0	2880.00	0	
9/83 - 1/84	3600	0	408.00	3192.00	0	
9/83 - 2/84	4320	0	408.00	3912.00	0	
9/83 - 3/84	5040	0	408.00	4632.00	0	
9/83 - 4/84	5760	0	408.00	5352.00	0	
9/83 - 5/84	6480	0	408.00	6072.00	0	
9/83 - 6/84	7200	0	408.00	6792.00	0	

TABLE B-14. SYSTEM AND SENSOR DATA FOR VALDEZ, ALASKA (CONTINUED)

E. Temperature Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	312.00	408.00	0	
9/83 - 10/83	1440	0	457.00	983.00	0	
9/83 - 11/83	2160	0	457.00	1703.00	0	
9/83 - 12/83	2880	0	769.00	2111.00	0	
9/83 - 1/84	3600	0	1177.00	2423.00	0	
9/83 - 2/84	4320	0	1177.00	3143.00	0	
9/83 - 3/84	5040	0	1177.00	3863.00	0	
9/83 - 4/84	5760	0	1177.00	4583.00	0	
9/83 - 5/84	6480	0	1177.00	5303.00	0	
9/83 - 6/84	7200	0	1177.00	6023.00	0	

F. Dewpoint Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	720.00	0	0	1	
9/83 - 10/83	1440	1440.00	0	0	1	
9/83 - 11/83	2160	1632.00	0	528.00	1	
9/83 - 12/83	2880	1632.00	312.00	936.00	1	
9/83 - 1/84	3600	1632.00	720.00	1248.00	1	
9/83 - 2/84	4320	1632.00	720.00	1968.00	1	
9/83 - 3/84	5040	1632.00	720.00	2688.00	1	
9/83 - 4/84	5760	1632.00	720.00	3408.00	1	
9/83 - 5/84	6480	1632.00	720.00	4128.00	1	
9/83 - 6/84	7200	1632.00	720.00	4848.00	1	

TABLE B-14. SYSTEM AND SENSOR DATA FOR VALDEZ, ALASKA (CONTINUED)

C. Visibility Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	0	720.00	0	
9/83 - 10/83	1440	0	145.00	1295.00	0	
9/83 - 11/83	2160	0	145.00	2015.00	0	
9/83 - 12/83	2880	0	457.00	2423.00	0	
9/83 - 1/84	3600	0	865.00	2735.00	0	
9/83 - 2/84	4320	0	865.00	3455.00	0	
9/83 - 3/84	5040	0	865.00	4175.00	0	
9/83 - 4/84	5760	0	865.00	4895.00	0	
9/83 - 5/84	6480	0	865.00	5615.00	0	
9/83 - 6/84	7200	0	865.00	6335.00	0	

D. Wind Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	0	312.00	408.00	0	
9/83 - 10/83	1440	0	457.00	983.00	0	
9/83 - 11/83	2160	0	457.00	1703.00	0	
9/83 - 12/83	2880	0	769.00	2111.00	0	
9/83 - 1/84	3600	0	1177.00	2423.00	0	
9/83 - 2/84	4320	0	1177.00	3143.00	0	
9/83 - 3/84	5040	264.00	1177.00	3599.00	2	1799.50
9/83 - 4/84	5760	264.00	1177.00	4319.00	2	2159.50
9/83 - 5/84	6480	264.00	1177.00	5039.00	2	2519.50
9/83 - 6/84	7200	264.00	1177.00	5759.00	2	2879.50

TABLE B-14. SYSTEM AND SENSOR DATA FOR VALDEZ, ALASKA

A. System Data

Period	Total Time (hrs)	Total Time To Restore (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	312.00	408.00	1	
9/83 - 10/83	1440	457.00	983.00	5	196.60
9/83 - 11/83	2160	457.00	1703.00	5	340.60
9/83 - 12/83	2880	969.00	2111.00	6	351.83
9/83 - 1/84	3600	1177.00	2423.00	6	403.83
9/83 - 2/84	4320	1177.00	3143.00	6	523.83
9/83 - 3/84	5040	1177.00	3863.00	6	643.83
9/83 - 4/84	5760	1177.00	4583.00	6	763.83
9/83 - 5/84	6480	1177.00	5303.00	6	883.83
9/83 - 6/84	7200	1177.00	6023.00	6	1003.83

B. Ceiling Sensor Data

Period	Total Time (hrs)	Total Time to Restore (hrs)	Down Time Due to System Failure (hrs)	TOT (hrs)	No. of Failures	MTBF (hrs)
9/83	720	720.00	0	0	1	
9/83 - 10/83	1440	816.00	145.00	479.00	1	
9/83 - 11/83	2160	816.00	145.00	1199.00	1	
9/83 - 12/83	2880	816.00	457.00	1607.00	1	
9/83 - 1/84	3600	816.00	865.00	1919.00	1	
9/83 - 2/84	4320	816.00	865.00	2639.00	1	
9/83 - 3/84	5040	816.00	865.00	3359.00	1	
9/83 - 4/84	5760	816.00	865.00	4079.00	1	
9/83 - 5/84	6480	816.00	865.00	4799.00	1	
9/83 - 6/84	7200	816.00	865.00	5519.00	1	

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Wind	PWT	None			
	SAF	None			
	VDZ	1	3/84	3/84	Wind sensor error/defrost frozen sensor
		2	3/84	3/84	Wind sensor error/defrost frozen sensor
Temperature	DCA	None			
	HUM	None			
	DBQ	None			
	CMX	None			
	PWT	None			
	SAF	1	10/83	10/83	Temp miss/cleaned & dried moisture in temp sensor
	VDZ	None			
Dew Point	DCA	1	5/84	6/84	Dewpoint sensor out/unresolved
	HUM	1	12/83	12/83	Dewpoint miss/water in transmitter box dried, cleaned
		2	12/83	12/83	Dewpoint reading incorrect/self correcting
		3	2/84	2/84	Dewpoint miss/dried moisture from transmitter box
		4	2/84	3/84	Dewpoint erratic/cleaned & recharged dewpoint cell
	DBQ	1	11/83	11/83	Dewpoint miss/hardware reset
		2	11/83	11/83	Dewpoint miss/replaced fuse to sensor fan motor
	CMX	1	2/84	2/84	Dewpoint miss/replaced fuse to sensor fan motor
	PWT	1	3/84	3/84	Dewpoint miss/problem self correcting
	SAF	None			
	VDZ	1	9/83	11/83	Sensor out of service/sensor adjusted
Precipitation	DCA	1	2/84	6/84	No precip/unresolved
	HUM	1	3/84	3/84	Precip errors/contaminated scotch tape on sensors, cleaned & replaced
		2	3/84	3/84	Precip errors/contaminated scotch tape on sensors, cleaned & replaced
	DBQ	None			

TABLE C-2. HISTORICAL ACCOUNT OF ARTAIS SYSTEM AND SENSOR FAILURES BY SITE (CONTINUED)

Artais	Site ID	Failure No.	Mo/Yr Occurred	Mo/Yr Resolved	Causes of Failure/Corrective Action
Precipitation	CMX	1	9/83	3/84	Sensor error/tipping bucket cover w/new type heating element (installed)
		2	5/84	6/84	Sensor error/bad wong sensor (unresolved)
	PWT	None			
	SAF	None			
	VDZ	None			
Altimeter	DCA	1	10/83	10/83	Alt off by .05/alt correction made
	HUM	None			
	DBQ	1	1/84	1/84	Alt intermittently miss/loose connector on alt equip
	CMX	1	11/83	11/83	Alt miss/reset at master weather processor (MWP)
	PWT	None			
	SAF	None			
	VDZ	None			

APPENDIX D

AUTOMATED WEATHER OBSERVING SYSTEM DEMONSTRATION PROGRAM

AWOS VERSUS OFFICIAL COMPARISON ANALYSIS
DATA TABLES AND FIGURES

Results of the AWOS versus official comparison analysis for the nine meteorological sensors and thirteen AWOS sites are given in tables D-1 through D-13 in this appendix. In addition, a complete set of plots for Washington, D.C. (DCA), and Houston, Texas (HOU), is displayed in figures D-1 through D-30. The following information is provided in the data tables:

1. AWOS site call letters or identifier "sta".

2. Sample size "N". Number of data pairs compared.

3. Linear correlation coefficient "r" between AWOS and official values.

4. Linear regression slope "a" of AWOS on official values.

5. Linear regression y-intercept "b" of AWOS on official values.

6. Mean difference or bias "d". Arithmetic sample mean value of differences (AWOS minus official.)

7. Sample standard deviation "s_d" of AWOS minus official values.

8. rms value "d_{rms}" of AWOS minus official values.

9. Reliability index "RI". Percentage of "N" differences within acceptance limits described in table D-19.

Statistical significance tests were conducted on all linear correlation coefficient, mean difference, sample standard deviation, and reliability index values. An asterisk "*" following these estimates denotes that the computed statistic is not statistically significant at the 95 percent confidence level according to the prescribed acceptance intervals, i.e., insufficient sample size.

The following additional information is also given for cross-reference:

1. Method used to obtain official sky and ceiling reports (table 3, text). "RBC" means rotating beam ceilometer; "EST" means estimated by official observer.

2. AWOS visibility sensor type (table 4, text).

3. AWOS site magnetic variation or compass declination ("Mag" in table D-8). This is the angle, in degrees, between true north and magnetic north. It is either "east" or "west" according to whether the compass needle points to the east or west of true or geographic north. Generally, eastern AWOS sites have west declinations while western AWOS sites have east declinations. To convert wind direction from magnetic to true, add east declinations to the magnetic direction, and subtract west declinations from the magnetic direction.

TABLE D-1. CLOUD LAYER NUMBER

Sta	Clear	N		Distribution in Percent						
			$(N_A - N_O)$	-3	-2	-1	0	+1	+2	+3
CMX	953	1206		0.0	0.5	15.2	60.4	17.2	6.7	0.1
DBQ	584	633		0.0	0.8	16.9	42.5	32.4	7.1	0.3
DCA	1531	1339		0.0	2.5	43.2	41.2	11.9	1.1	0.0
HUM	523	838		0.0	2.9	33.8	41.4	16.5	5.3	0.2
PWT	20	128		0.0	4.7	32.8	36.7	22.7	3.1	0.0
SAF	99	15		0.0	0.0	66.7	20.0	13.3	0.0	0.0
VDZ	274	370		1.6	13.2	53.8	25.4	5.4	0.5	0.0
EEN	199	643		0.0	1.4	20.2	30.9	37.2	9.8	0.5
GAL	790	1995		0.1	2.4	27.1	29.4	28.0	11.5	1.7
HOU	1538	2390		0.3	4.8	27.8	33.1	20.7	9.2	4.0
MIE	557	566		0.4	8.5	59.2	25.3	5.8	0.9	0.0
PSP	2693	127		0.0	2.4	30.7	14.2	45.7	7.1	0.0
SBP	370	204		0.0	1.5	19.1	32.8	29.4	16.7	0.5

TABLE D-2. SKY OBSCURATION OCCURRENCE

Case	Overall				No Precip or Fog				Precipitation				Fog			
Sta	N	(A) no (O) yes	yes yes	yes no	N	no yes	yes yes	yes no	N	no yes	yes yes	yes no	N	no yes	yes yes	yes no
CMX	327	22.9	73.7	3.4	59	33.9	62.7	3.4	231	21.2	75.8	3.0	69	18.8	75.4	5.8
DBQ	190	11.1	35.8	53.2	77	0.0	13.0	87.0	79	25.3	50.6	24.1	81	11.1	55.6	33.3
DCA	92	12.0	77.2	10.9	1	0.0	0.0	100.0	44	6.8	79.5	13.6	80	12.5	80.0	7.5
HUM	37	21.6	32.4	45.9	10	0.0	20.0	80.0	3	0.0	33.3	66.7	27	29.6	37.0	33.3
VDZ	38	0.0	84.2	15.8	5	0.0	60.0	40.0	31	0.0	87.1	12.9	6	0.0	100.0	0.0
EEN	72	22.2	76.4	1.4	1	100.0	0.0	0.0	40	12.5	85.0	2.5	61	19.7	80.3	0.0
GAL	82	4.9	63.4	31.7	27	3.7	44.4	51.9	15	20.0	66.7	13.3	40	0.0	75.0	25.0
HOU	134	23.9	59.0	17.2	3	0.0	0.0	100.0	30	40.0	40.0	20.0	113	24.8	58.4	16.8
MIE	11	9.1	81.8	9.1	1	0.0	100.0	0.0	2	0.0	100.0	0.0	1	0.0	100.0	0.0
PSP	26	15.4	7.7	76.9	6	0.0	33.3	66.7	0	0.0	0.0	0.0	2	100.0	0.0	0.0

TABLE D-3. CEILING OCCURRENCE

Case	Overall				No Precip or Fog				Precipitation				Fog			
Sta	N	(A) clr (O) ceil	ceil ceil	ceil clr	N	clr ceil	ceil ceil	ceil clr	N	clr ceil	ceil ceil	ceil clr	N	clr ceil	ceil ceil	ceil clr
CMX	884	5.0	93.2	1.8	338	9.8	88.5	1.8	465	2.4	95.7	1.9	146	0.0	97.3	2.7
DBQ	420	9.5	75.0	15.5	216	16.2	56.9	26.9	147	2.7	95.2	2.0	118	1.7	94.1	4.2
DCA	837	9.9	86.6	3.5	332	21.1	72.0	6.9	304	4.3	95.1	0.7	378	0.8	97.9	1.3
HUM	439	15.5	83.1	1.4	285	20.4	79.3	0.4	44	6.8	90.9	2.3	135	5.9	90.4	3.7
PWT	63	12.7	82.5	4.8	22	27.3	72.7	0.0	15	6.7	86.7	6.7	35	2.9	91.4	5.7
VDZ	136	41.9	57.4	0.7	63	54.0	44.4	1.6	67	31.3	68.7	0.0	10	20.0	80.0	0.0
EEN	283	11.7	86.2	2.1	101	19.8	79.2	1.0	82	1.2	97.6	1.2	105	1.9	97.1	1.0
GAL	669	14.6	40.5	44.8	451	13.1	30.2	56.8	188	20.7	66.5	12.8	32	0.0	31.3	68.8
HOU	1192	25.9	58.1	15.9	425	34.5	64.5	0.7	142	16.9	83.1	0.0	391	11.0	85.7	3.3
MIE	289	70.2	27.3	2.4	133	91.0	9.0	0.0	50	50.0	50.0	0.0	68	55.9	44.1	0.0
PSP	48	18.8	35.4	45.8	14	21.4	28.6	50.0	7	14.3	85.7	0.0	11	0.0	100.0	0.0
SBP	85	0.0	64.7	35.3	41	0.0	36.6	63.4	0	0.0	0.0	0.0	44	0.0	90.9	9.1

TABLE D-4. CLOUD HEIGHT

OVERALL

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	830	0.73	0.71	27	-381	800	886	56
DBQ	RBC	236	0.84	1.02	-41	-19	600	599	70 *
DCA	RBC	575	0.89	0.90	-42	-164	411	442	80
HUM	EST	472	0.77	0.81	343	-19	857	856	64
PWT	EST	75	0.92	0.96	199	133 *	568 *	580	64 *
VDZ	EST	110	0.53	0.38	107	-1542 *	1224 *	1966	20 *
EEN	EST	390	0.69	0.72	981	406 *	1102	1173	42
GAL	RBC	93	0.64	0.83	791	446 *	1069 *	1153	62 *
HOU	RBC	855	0.65	0.90	575	450	1012	1107	66
MIE	RBC	177	0.81	0.84	208	-11 *	683	681	78 *
PSP	EST	28	0.91	0.86	107	-225 *	663 *	688	46 *
SBP	EST	60	0.80	0.93	142	78 *	734 *	732	82 *

OFFICIAL > 1500 FEET

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	283	0.49	0.70	48	-730 *	1146 *	1357	52 *
DBQ	RBC	65	0.51	1.05	-137	-13 *	1095 *	1087	38 *
DCA	RBC	159	0.61	0.99	-272	-305 *	665	730	74 *
HUM	EST	254	0.49	0.59	1047	-105 *	1118 *	1120	58 *
PWT	EST	23	0.75	0.84	551	39 *	854 *	836	52 *
VDZ	EST	79	0.36	0.39	57	-1979 *	1155 *	2288	10 *
EEN	EST	189	0.58	0.72	958	58 *	1016 *	1015	49 *
GAL	RBC	66	0.55	0.78	929	362 *	857 *	924	64 *
HOU	RBC	252	0.47	0.66	1205	335 *	819	883	60 *
MIE	RBC	61	0.61	0.72	563	-170 *	931 *	939	61 *
PSP	EST	14	0.84	1.04	-645	-507 *	594 *	764	43 *

OFFICIAL ≤ 1500 FEET

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	547	0.60	0.67	48	-201	445	488	57
DBQ	RBC	171	0.90	1.07	-67	-21	214	214	82 *
DCA	RBC	416	0.82	0.88	-26	-111	233	258	83
HUM	EST	218	0.82	1.18	-74	79	344	352	72 *
PWT	EST	52	0.87	1.40	-120	175 *	384	419	69 *
VDZ	EST	31	0.38	0.25	224	-429 *	436 *	606	45 *
EEN	EST	201	0.28	0.77	942	733 *	1081 *	1304	36 *
GAL	RBC	27	0.26 *	0.96	678	651 *	1464 *	1577	59 *
HOU	RBC	603	0.39	1.08	437	498	1080	1188	68
MIE	RBC	116	0.55	0.96	101	72	492	495	87 *
PSP	EST	14	0.68	1.68	-523	57 *	623 *	603	50 *
SBP	EST	53	0.37	0.81	205	90 *	764 *	763	83 *

NO PRECIPITATION OR FOG

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	308	0.81	0.79	139	-210	754	781	67 *
DBQ	RBC	90	0.90	1.16	-52	226 *	504	550	76 *
DCA	RBC	138	0.93	0.90	135	-77	293	302	83 *
HUM	EST	305	0.73	0.73	654	39	885	885	63 *
PWT	EST	38	0.89	0.90	464	242 *	641 *	677	53 *
VDZ	EST	28	0.70	0.54	300	-1217 *	1012 *	1572	21 *
EEN	EST	151	0.76	0.76	973	292 *	848 *	894	56 *
GAL	RBC	50	0.95	1.16	-341	12 *	429 *	425	74 *
HOU	RBC	384	0.68	0.87	593	357	315	889	63
MIE	RBC	43	0.66	0.62	681	-79 *	869 *	862	77 *
SBP	EST	14	0.98	0.93	4	-135 *	261 *	286	71 *

TABLE D-4. CLOUD HEIGHT (CONTINUED)

PRECIPITATION

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	455	0.42	0.34	212	-542	843	1001	44
DBQ	RBC	110	0.65	0.59	85	-269 *	653 *	704	64 *
DCA	RBC	261	0.72	0.68	54	-262	533	593	69 *
HUM	EST	57	0.72	0.77	51	-256 *	816 *	848	65 *
PWT	EST	20	0.68	0.65	258	-30 *	596 *	582	70 *
VDZ	EST	79	0.37	0.20	311	-1635 *	1293 *	2079	20 *
EEN	EST	121	0.52	0.61	1495	977 *	1159 *	1512	28 *
GAL	RBC	34	-0.01 *	-0.01	3095	1014 *	1256 *	1600	41 *
HOU	RBC	134	0.66	0.89	328	240 *	807 *	839	70 *
MIE	RBC	53	0.78	0.82	153	-62 *	726 *	722	72 *

FOG

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	138	0.55	0.36	208	-271 *	666	717	72 *
DBQ	RBC	82	0.88	1.05	-65	-36	374	374	82 *
DCA	RBC	342	0.85	0.80	13	-138	319	347	84
HUM	EST	137	0.75	0.81	127	-102 *	752 *	756	71 *
PWT	EST	33	0.90	0.83	151	57	212	216	82 *
VDZ	EST	13	0.41 *	0.19	129	-2038 *	1140 *	2314	8 *
EEN	EST	149	0.49	0.66	1143	761 *	1187 *	1407	29 *
GAL	RBC	10	-0.43 *	-3.64	1929	630 *	1617 *	1659	80 *
HOU	RBC	366	0.47	0.90	362	298	922	968	78
MIE	RBC	66	0.73	0.75	226	-56 *	724 *	721	77 *
PSP	EST	14	0.67	0.74	248	-57 *	707 *	684	36 *
SBP	EST	42	0.70	0.83	47	-40	287	286	90 *

OFFICIAL CEILING VERSUS AWOS CEILING

Sta	Sen	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	EST	648	0.76	0.76	-69	-372	704	795	58
DBQ	RBC	188	0.84	1.00	-31	-28	515	514	73 *
DCA	RBC	474	0.90	0.89	-40	-162	384	417	82
HUM	EST	277	0.87	0.95	92	14	643	642	74 *
PWT	EST	42	0.95	0.91	167	85 *	361	367	69 *
VDZ	EST	62	0.57	0.43	-25	-1327 *	1142 *	1745	19 *
EEN	EST	165	0.67	0.68	715	175 *	1005 *	1018	49 *
GAL	RBC	48	0.76	1.11	232	400 *	942 *	1015	65 *
HOU	RBC	447	0.94	1.03	73	98	287	303	86
MIE	RBC	66	0.98	1.00	1	-1	122	121	95 *
PSP	EST	13	0.88	0.85	205	-30 *	588 *	662	54 *
SBP	EST	46	0.96	0.92	1	-56	166	174	91 *

TABLE D-5. VISIBILITY OCCURRENCE

Case Sta	Sensor	Clear	Overall N	Overall (A) >5 (O) ≤5	Overall ≤5 ≤5	Overall ≤5 >5	No Precip or Fog N	No Precip or Fog >5 ≤5	No Precip or Fog ≤5 ≤5	No Precip or Fog ≤5 >5	Precipitation N	Precipitation >5 ≤5	Precipitation ≤5 ≤5	Precipitation ≤5 >5	Fog N	Fog >5 ≤5	Fog ≤5 ≤5	Fog ≤5 >5
CMX	FWDSCAT	1521	510	20.6	76.5	2.9	16	25.0	37.5	37.5	430	16.3	81.9	1.9	144	29.9	68.8	1.4
DBQ	T(1000)	864	751	4.1	38.2	57.7	448	2.2	8.0	89.7	201	8.5	77.1	14.4	214	5.6	92.1	2.3
DCA	FWDSCAT	2471	536	37.3	57.8	4.9	65	78.5	6.2	15.4	273	24.2	71.1	4.8	379	31.7	67.3	1.1
HUM	FWDSCAT	970	381	62.2	29.1	8.7	169	76.9	5.9	17.2	56	42.9	51.8	5.4	184	48.9	50.5	0.5
PWT	T(1000)	101	68	11.8	47.1	41.2	23	0.0	0.0	100.0	25	12.0	72.0	16.0	41	19.5	78.0	2.4
SAF	T(1000)	77	38	0.0	0.0	100.0	35	0.0	0.0	100.0	3	0.0	0.0	100.0	0	0.0	0.0	0.0
VDZ	FWDSCAT	539	192	7.8	45.3	46.9	75	1.3	4.0	94.7	110	11.8	71.8	16.4	23	13.0	73.9	13.0
EEN	BCKSCAT	363	511	10.6	28.4	61.1	294	0.3	1.0	98.6	119	11.8	75.6	12.6	150	15.3	81.3	3.3
GAL	BCKSCAT	2325	466	8.4	35.2	56.4	219	0.9	0.0	99.1	159	15.7	57.9	26.4	91	14.3	81.3	4.4
HOU	T(492)	1688	2823	3.5	26.9	69.6	1861	0.8	8.5	90.7	200	7.0	72.5	20.5	589	8.1	82.5	9.3
MIE	T(492)	1170	688	35.3	40.3	24.4	202	25.2	3.0	71.8	203	32.5	65.0	2.5	328	43.3	52.7	4.0
PSP	T(492)	2655	124	8.1	18.5	73.4	58	5.2	13.8	81.0	8	12.5	87.5	0.0	14	35.7	64.3	0.0
SBP	T(492)	415	137	31.4	13.1	55.5	75	2.7	0.0	97.3	5	0.0	60.0	40.0	57	71.9	28.1	0.0

TABLE D-6. VISIBILITY

OVERALL

Sta	Sensor	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	FWDSCAT	390	0.71	0.95	0.80	0.72	0.99	1.23	57
DBQ	T(1000)	287	0.63	0.65	0.58	-0.22	1.24	1.26	64 *
DCA	FWDSCAT	310	0.66	0.76	0.66	0.13	1.25	1.26	67 *
HUM	FWDSCAT	111	0.53	0.52	1.24	-0.12 *	1.37	1.37	65 *
PWT	T(1000)	32	0.15 *	0.20	1.24	-1.02 *	2.06 *	2.27	41 *
VDZ	FWDSCAT	87	0.47	0.54	0.64	-0.32 *	1.48 *	1.50	52 *
EEN	BCKSCAT	145	0.68	0.74	1.23	0.72	1.25	1.44	59 *
GAL	BCKSCAT	164	0.55	0.62	1.48	0.64	1.34	1.48	49 *
HOU	T(492)	759	0.61	0.48	1.51	-0.14	1.31	1.32	61
MIE	T(492)	277	0.61	0.68	1.57	0.83	1.26	1.50	55 *
PSP	T(492)	23	0.73	0.74	1.27	0.36 *	0.93 *	0.98	87 *
SBP	T(492)	18	0.59	0.64	1.64	0.99 *	1.52 *	1.77	39 *

OFFICIAL > 2 MILES

Sta	Sensor	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	FWDSCAT	51	0.28	0.34	2.65	0.32 *	1.06 *	1.10	78 *
DBQ	T(1000)	135	0.23	0.35	1.66	-0.66	1.41	1.55	59 *
DCA	FWDSCAT	170	0.17	0.30	2.27	-0.06	1.50	1.50	68 *
HUM	FWDSCAT	71	0.16 *	0.20	2.46	-0.48 *	1.41 *	1.48	69 *
PWT	T(1000)	18	-0.19 *	-0.42	3.71	-1.71 *	2.16 *	2.71	44 *
VDZ	FWDSCAT	34	-0.02 *	-0.04	2.66	-0.96 *	1.84 *	2.05	53 *
EEN	BCKSCAT	46	0.07 *	0.06	3.86	0.18 *	1.19 *	1.20	78 *
GAL	BCKSCAT	73	0.09 *	0.15	3.15	0.18 *	1.44 *	1.44	63 *
HOU	T(492)	501	0.16	0.17	2.81	-0.63	1.21	1.36	67
MIE	T(492)	128	0.15 *	0.18	3.28	0.38	1.22	1.27	70 *
PSP	T(492)	18	0.38 *	0.43	2.60	0.28 *	0.96 *	0.97	94 *

OFFICIAL ≤ 2 MILES

Sta	Sensor	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	FWDSCAT	339	0.68	1.34	0.42	0.78	0.97	1.24	54 *
DBQ	T(1000)	152	0.62	1.06	0.09	0.16	0.91	0.92	68 *
DCA	FWDSCAT	140	0.72	1.29	0.15	0.36	0.81	0.88	66 *
HUM	FWDSCAT	49	0.63	1.21	0.26	0.53 *	1.02 *	1.14	58 *
PWT	T(1000)	14	0.37 *	0.99	-0.12	-0.13 *	1.58 *	1.53	36 *
VDZ	FWDSCAT	53	0.53	1.00	0.08	0.08 *	1.02	1.01	51 *
EEN	BCKSCAT	99	0.68	1.97	-0.08	0.97	1.20	1.54	51 *
GAL	BCKSCAT	91	0.50	1.18	0.77	1.00	1.15	1.52	38 *
HOU	T(492)	258	0.69	1.34	0.40	0.82	0.91	1.23	50 *
MIE	T(492)	149	0.73	1.83	0.16	1.21	1.16	1.68	41 *
SBP	T(492)	12	0.54 *	2.00	0.54	1.40 *	1.49 *	1.99	25 *

TABLE D-6. VISIBILITY (CONTINUED)

PRECIPITATION

Sta	Sensor	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	FWDSCAT	352	0.71	0.96	0.80	0.74	0.95	1.20	55 *
DBQ	T(1000)	155	0.62	0.68	0.54	-0.15	1.09	1.09	65 *
DCA	FWDSCAT	194	0.57	0.65	0.86	0.01	1.37	1.37	65 *
HUM	FWDSCAT	29	0.53	0.56	1.12	-0.01 *	1.28 *	1.26	62 *
PWT	T(1000)	18	-0.03 *	-0.07	2.40	-0.63 *	2.00 *	2.04	39 *
VDZ	FWDSCAT	79	0.52	0.58	0.67	-0.21 *	1.42 *	1.43	54 *
EEN	BCKSCAT	90	0.66	0.73	1.19	0.69 *	1.26	1.43	66 *
GAL	BCKSCAT	92	0.57	0.59	1.85	0.71	1.12	1.31	59 *
HOU	T(492)	145	0.64	0.53	1.45	0.42	1.11	1.18	56 *
MIE	T(492)	132	0.63	0.77	1.25	0.76	1.18	1.40	59 *

FOG

Sta	Sensor	N	r	a	b	$\bar{d}$	s	rms	RI
CMX	FWDSCAT	99	0.70	1.00	0.62	0.63	1.17	1.32	65 *
DBQ	T(1000)	197	0.71	0.73	0.47	-0.10	1.09	1.10	70 *
DCA	FWDSCAT	255	0.68	0.82	0.57	0.17	1.21	1.22	69 *
HUM	FWDSCAT	93	0.57	0.59	1.15	0.05 *	1.29	1.28	67 *
PWT	T(1000)	32	0.15 *	0.20	1.24	-1.02 *	2.06 *	2.27	41 *
VDZ	FWDSCAT	17	0.17 *	0.29	0.78	-0.54 *	1.67 *	1.71	41 *
EEN	BCKSCAT	122	0.69	0.79	1.18	0.77	1.22	1.44	58 *
GAL	BCKSCAT	74	0.33	0.39	1.52	0.52 *	1.58 *	1.66	39 *
HOU	T(492)	486	0.68	0.56	1.27	0.07	1.15	1.15	66
MIE	T(492)	173	0.62	0.66	1.67	0.89	1.19	1.48	58 *
SBP	T(492)	16	0.66	0.77	1.54	1.17 *	1.41 *	1.80	38 *

TABLE D-7. TEMPERATURE

Sta	N	r	a	b	$\overline{d}$	s	rms	RI
CMX	2033	1.00	0.97	0.7	-0.2	1.7	1.7	96
DBQ	1591	1.00	0.97	0.3	-0.7	1.5	1.7	97
DCA	2968	1.00	1.00	-1.2	-1.0	1.3	1.6	98
PWT	133	0.99	0.96	1.7	-0.2	1.4	1.4	97
SAF	114	0.98	0.96	2.9	0.1	1.8	1.8	96
VDZ	593	0.99	0.96	-0.1	-1.4	1.9	2.3	89
EEN	887	0.99	0.97	0.6	-0.5	2.2	2.3	90
GAL	2762	1.00	1.04	-3.4	-2.9	3.0	4.1	63
HOU	4328	1.00	0.99	0.4	0.0	1.0	1.0	99
MIE	984	1.00	0.98	0.4	-0.5	1.7	1.8	94

TABLE D-8. DEW POINT

Sta	N	r	a	b	$\overline{d}$	s	rms	RI	
CMX	1928	0.98	0.99	-2.8	-3.2	3.1	4.4	72	
DBQ	1566	0.99	0.93	2.3	0.9	3.3	3.4	87	
DCA	2735	0.99	0.89	-1.1	-4.6	2.6	5.3	48	
PWT	139	0.92	1.10	-7.3	-2.7	2.5	3.7	82	*
SAF	111	0.99	0.95	1.7	-0.1	1.3	1.3	100	
VDZ	533	0.97	0.93	-2.3	-4.3	3.4	5.4	57	
GAL	2373	1.00	1.01	0.2	0.2	2.4	2.4	94	
HOU	4387	0.99	0.93	2.7	-0.8	2.1	2.2	97	

TABLE D-9. ALTIMETER SETTING

Sta	N	r	a	b	$\overline{d}$	s	rms	RI
CMX	2041	1.00	1.02	-0.45	-0.002	0.008	0.008	100
DBQ	1504	1.00	1.06	-1.90	-0.003	0.012	0.013	100
DCA	2979	0.97	0.98	0.51	-0.008	0.008	0.012	100
HUM	1341	0.97	1.00	-0.03	-0.029	0.016	0.033	98
PWT	170	1.00	1.01	-0.36	0.020	0.009	0.022	100
SAF	114	0.98	1.00	0.00	-0.001	0.008	0.008	100
VDZ	708	0.99	0.98	0.67	-0.006	0.008	0.011	100
EEN	888	1.00	1.03	-0.95	-0.022	0.033	0.039	86
GAL	2777	0.97	0.99	0.20	-0.005	0.009	0.010	100
HOU	4185	1.00	1.04	-1.31	0.009	0.010	0.013	100
MIE	1831	1.00	1.03	-0.93	-0.009	0.013	0.015	100
PSP	2564	1.00	1.01	-0.30	0.008	0.013	0.015	100

TABLE D-10. WIND DIRECTION

Sta	N	r	a	b	$\bar{d}$	s	rms	RI	
CMX	1521	0.99	1.02	13	18	14	23	91	
DBQ	1328	0.99	0.98	11	7	13	15	98	
DCA	1945	0.99	0.99	6	4	16	17	96	
HUM	1018	0.98	0.97	0	-4	21	21	94	
PWT	74	0.97	0.87	-7	-38	22	44	47	*
SAF	82	0.93	0.93	15	1	38	37	76	*
VDZ	142	0.86	0.68	50	-14	50	52	44	*
EEN	303	0.93	0.84	55	12	34	36	69	*
CAL	225	0.97	0.95	2	-7	27	28	88	
HOU	2742	0.99	0.99	4	2	15	15	97	
MIE	1403	0.98	0.97	20	14	18	23	91	
PSP	903	0.94	0.98	24	19	37	41	72	

TABLE D-11. WIND SPEED

Sta	N	r	a	b	$\bar{d}$	s	rms	RI	
CMX	1533	0.82	0.92	0.3	-0.6	2.5	2.5	97	
DBQ	1328	0.88	0.95	0.4	-0.3	2.1	2.1	99	
DCA	1946	0.86	0.84	2.6	1.2	1.9	2.2	98	
HUM	1018	0.76	0.76	2.6	0.0	2.7	2.7	95	
PWT	74	0.45	0.40	5.2	-1.0	3.8	3.9	81	*
SAF	82	0.66	0.78	3.4	1.0	3.8	4.0	90	*
VDZ	141	0.66	0.31	5.4	0.3	3.4	3.4	92	
EEN	303	0.42	0.35	5.9	-0.7	3.7	3.8	85	
CAL	225	0.57	0.41	4.7	-0.1	3.0	3.0	90	
HOU	2912	0.78	0.80	1.3	-1.0	2.4	2.6	96	
MIE	1406	0.78	0.61	2.0	-3.7	3.0	4.8	74	
PSP	903	0.64	0.57	3.8	-1.2	3.7	3.9	85	

TABLE D-12. WIND GUST OCCURRENCE

Sta	N		Distribution in Percent		
		(A)	no	yes	yes
		(O)	yes	yes	no
CMX	483		22.2	52.6	25.3
DBQ	320		16.9	38.8	44.4
DCA	444		14.4	37.8	47.7
HUM	60		8.3	31.7	60.0
PWT	12		0.0	16.7	83.3
SAF	31		6.5	3.2	90.3
VDZ	26		61.5	15.4	23.1
EEN	93		7.5	14.0	78.5
CAL	41		56.1	7.3	36.6
HOU	510		8.6	30.8	60.6
MIE	23		8.7	34.8	56.5
PSP	93		0.0	24.7	75.3

TABLE D-13. WIND GUST SPEED

Sta	N	r	a	b	$\overline{d}$	s	rms	RI
CMX	254	0.81	0.81	3.5	-1.1	3.1	3.3	91
DBQ	124	0.86	0.85	3.8	-0.2	3.0	2.9	94
DCA	163	0.65	0.69	7.9	1.3	3.3	3.5	89
HUM	19	0.56	0.56	11.4	0.1	3.6	3.6	89 *
EEN	13	0.33 *	0.36	15.5	0.8 *	6.2 *	6.0	54 *
HOU	157	0.67	0.56	10.4	-0.1	4.4	4.4	85 *
PSP	23	0.26 *	0.17	21.4	0.0 *	6.2 *	6.1	57 *

TABLE D-14. PRECIPITATION OCCURRENCE

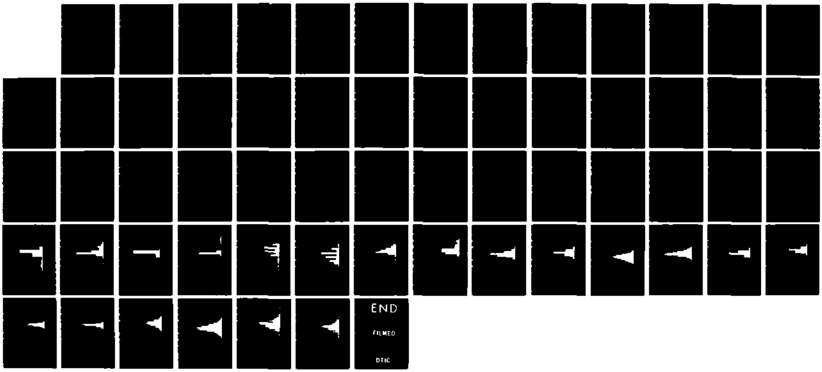
Sta	N		Distribution in Percent		
		(A) (O)	no yes	yes yes	yes no
CMX	580		85.3	10.2	4.5
DBQ	272		65.1	26.1	8.8
DCA	465		43.7	44.7	11.6
HUM	73		80.8	6.8	12.3
PWT	34		41.2	32.4	26.5
VDZ	147		73.5	24.5	2.0
EEN	158		24.7	57.0	18.4
GAL	368		86.7	7.3	6.0
HOU	284		35.2	38.7	26.1
MIE	292		46.9	33.6	19.5
PSP	14		64.3	14.3	21.4

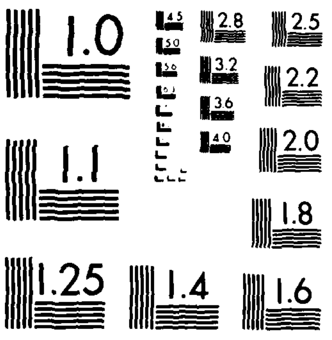
TABLE D-15. PRECIPITATION DETECTION BY TYPE

Official	Rain		Snow	
Sta	N	RI	N	RI
CMX	59	32.2	500	6.2
DBQ	107	47.7	148	14.9
DCA	379	52.5	44	27.3
HUM	64	7.8	0	0.0
PWT	25	44.0	0	0.0
VDZ	62	37.1	105	19.0
EEN	77	70.1	55	70.9
GAL	20	20.0	326	7.1
HOU	210	52.4	0	0.0
MIE	149	58.4	86	12.8
PSP	11	18.2	0	0.0

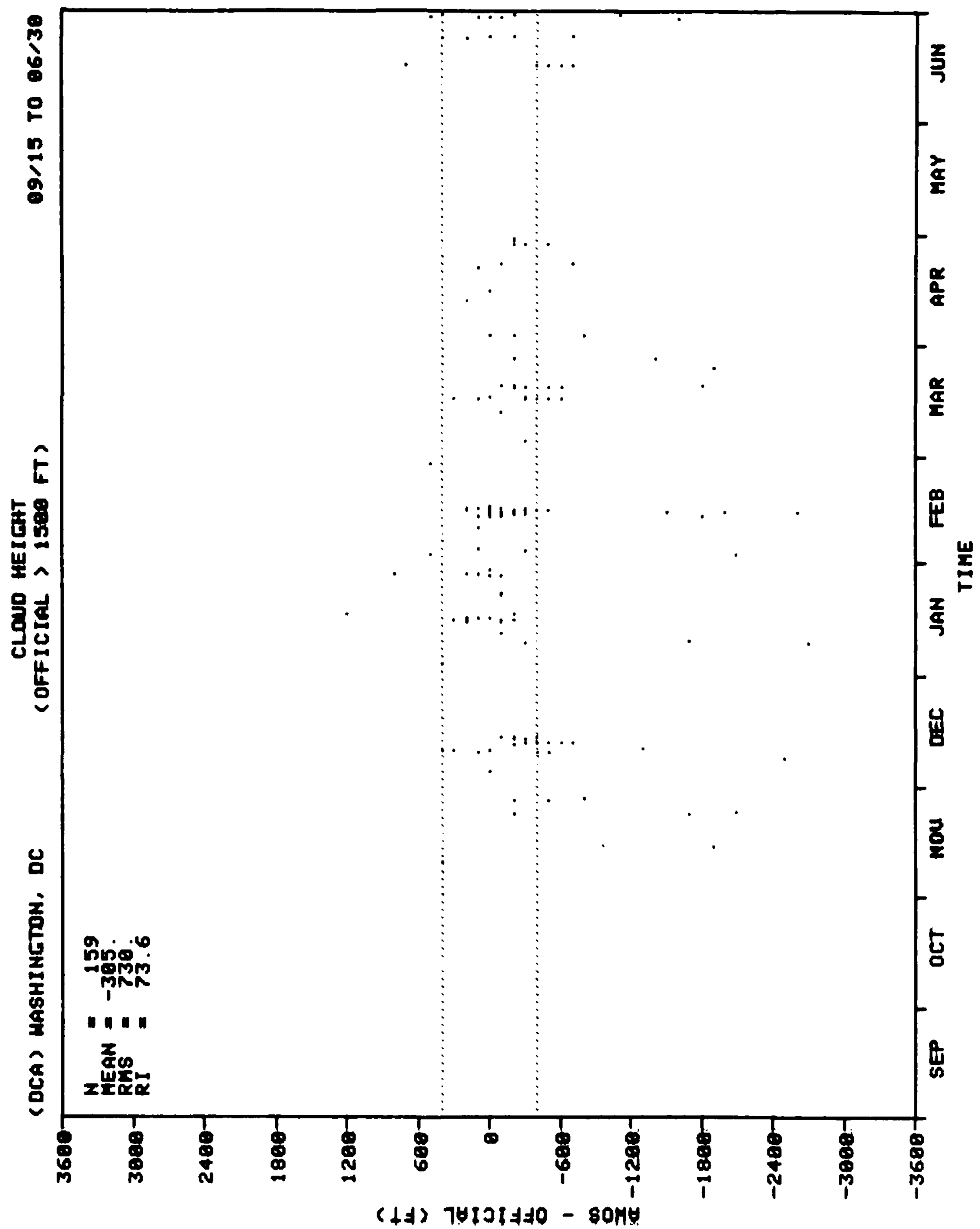
AD-A153 463 AUTOMATED WEATHER OBSERVING SYSTEM (AWOS) DEMONSTRATION PROGRAM(U) FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER ATLANTIC CIT.. P J O'BRIEN ET AL. SEP 84 3/3

UNCLASSIFIED DOT/FAA/CT-84/20 DOT/FAA-PM-85/1 F/G 4/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A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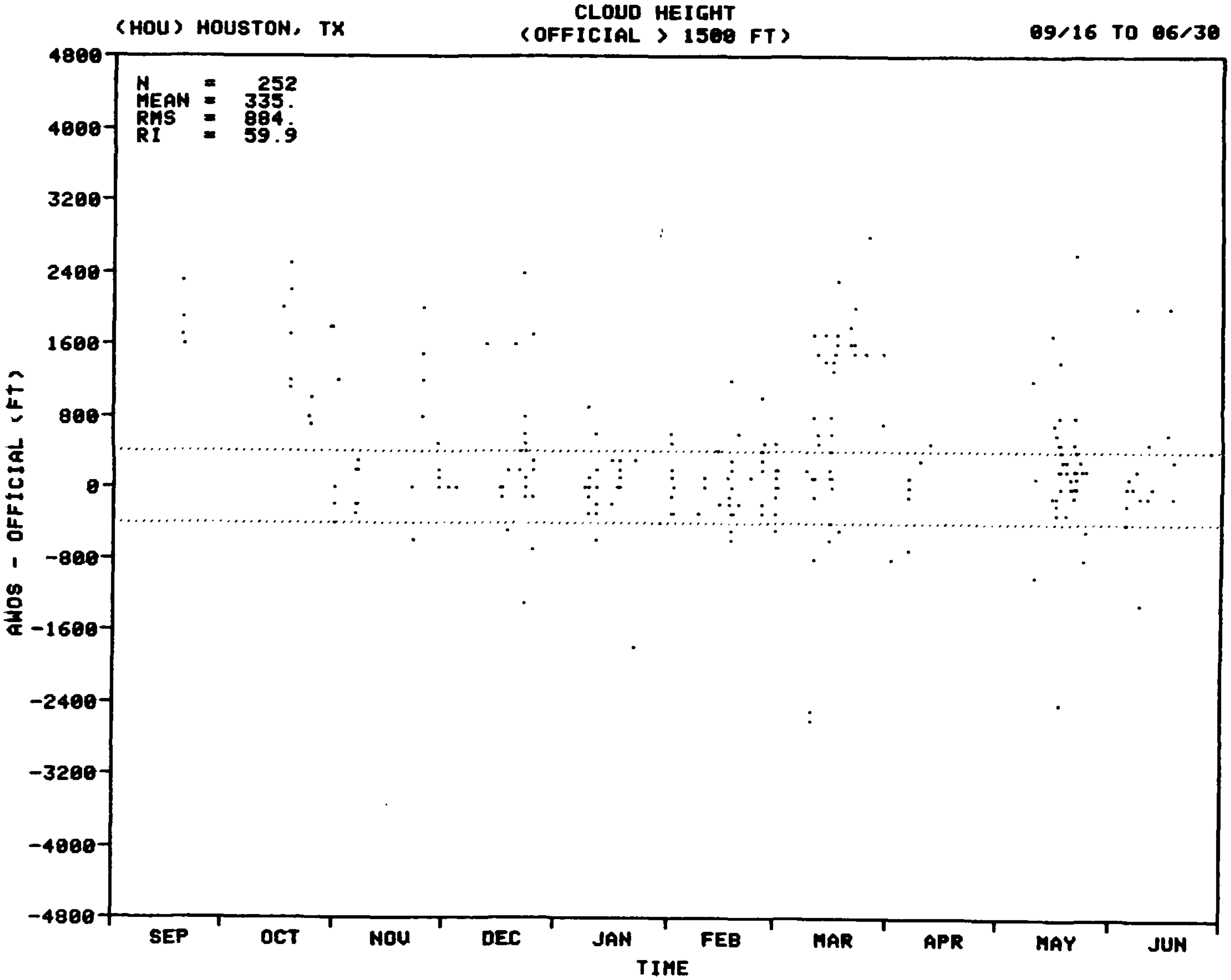
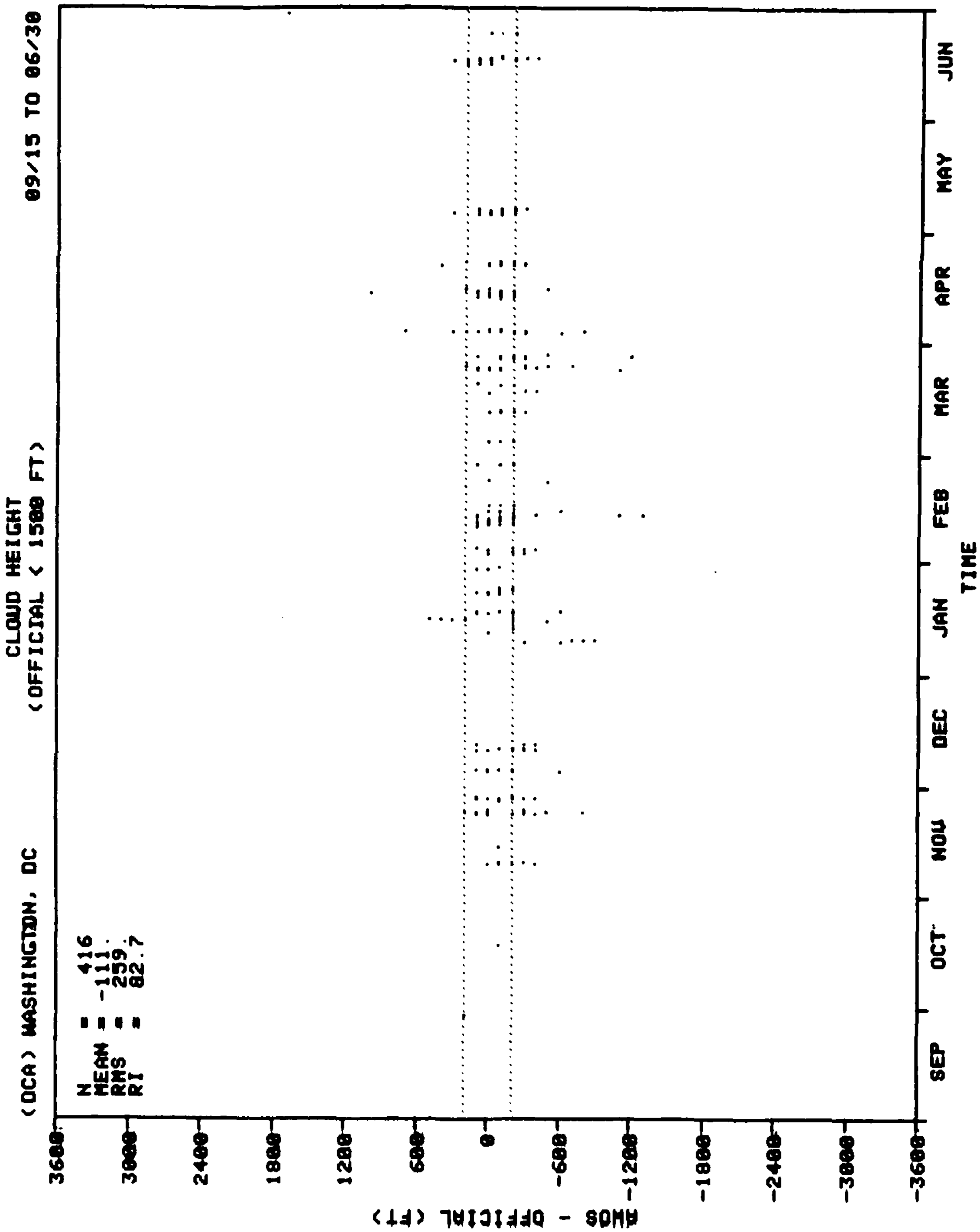
CLOUD HEIGHT
(OFFICIAL > 1500 FT)
09/15 TO 06/30
N = 159
MEAN = -305.
RMS = 730.
RI = 73.6
3600 3000 2400 1800 1200 600 0 -600 -1200 -1800 -2400 -3000 -3600
AMOS - OFFICIAL (FT)
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
TIME

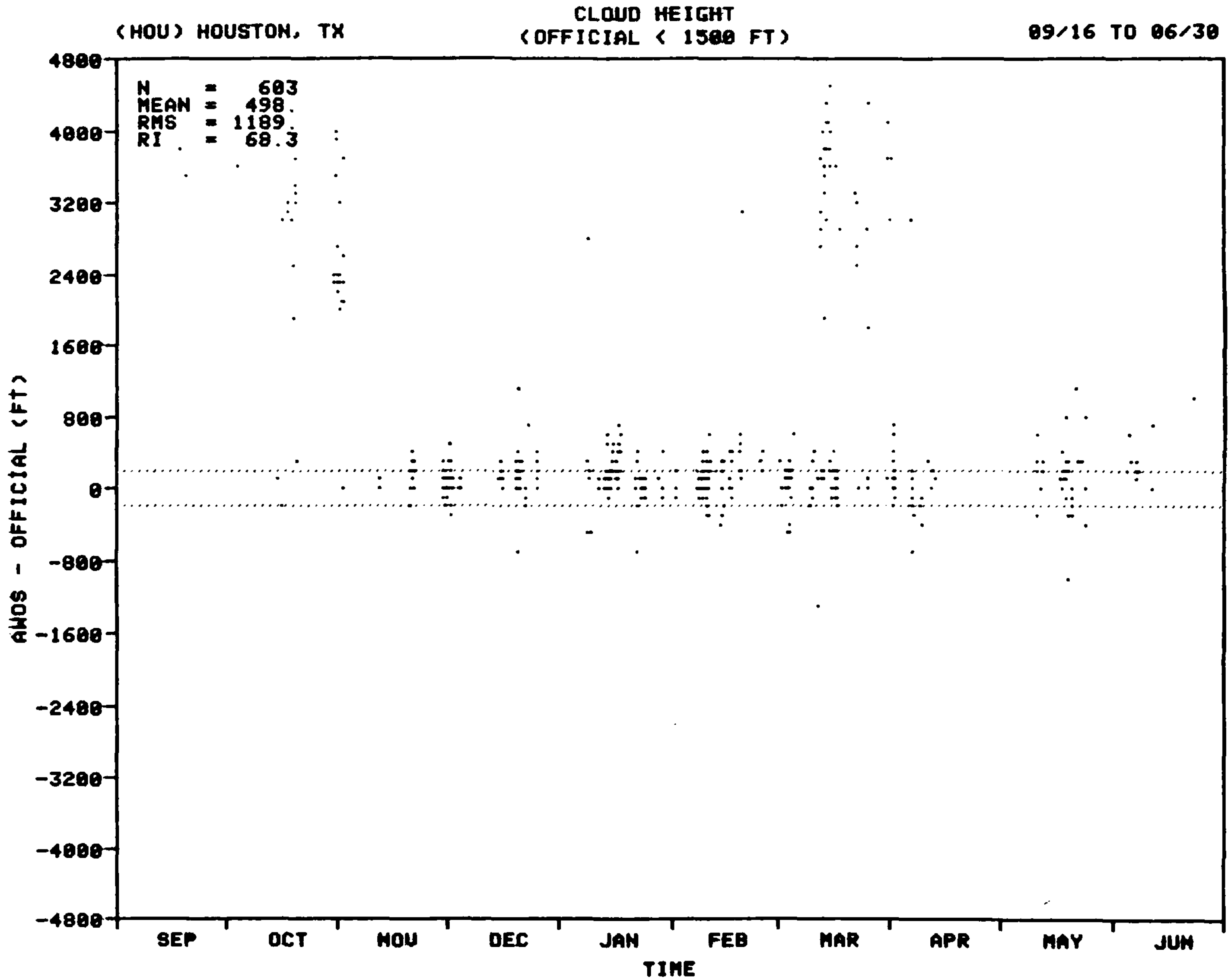
84-20-D-1a


(HOU) HOUSTON, TX
CLOUD HEIGHT
(OFFICIAL > 1500 FT)
09/16 TO 06/30
N = 252
MEAN = 335.
RMS = 884.
RI = 59.9
AWOS - OFFICIAL (FT)
4800
4000
3200
2400
1600
800
0
-800
-1600
-2400
-3200
-4000
-4800
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

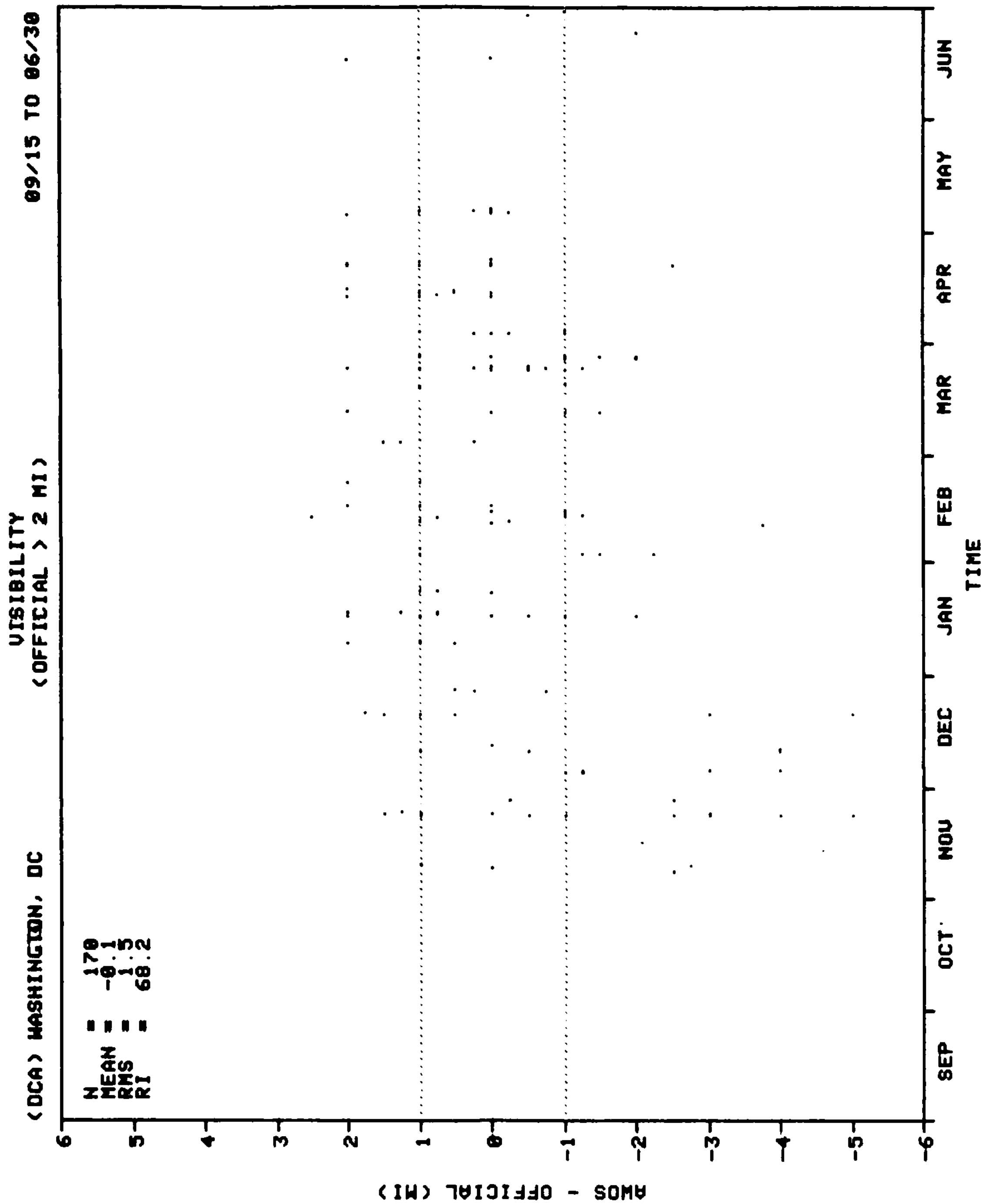
84-20-D-1b


(DCA) WASHINGTON, DC
CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/15 TO 06/30
N = 416
MEAN = -111
RMS = 259
RI = 82.7
AMOS - OFFICIAL (FT)
3600
3000
2400
1800
1200
600
0
-600
-1200
-1800
-2400
-3000
-3600
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

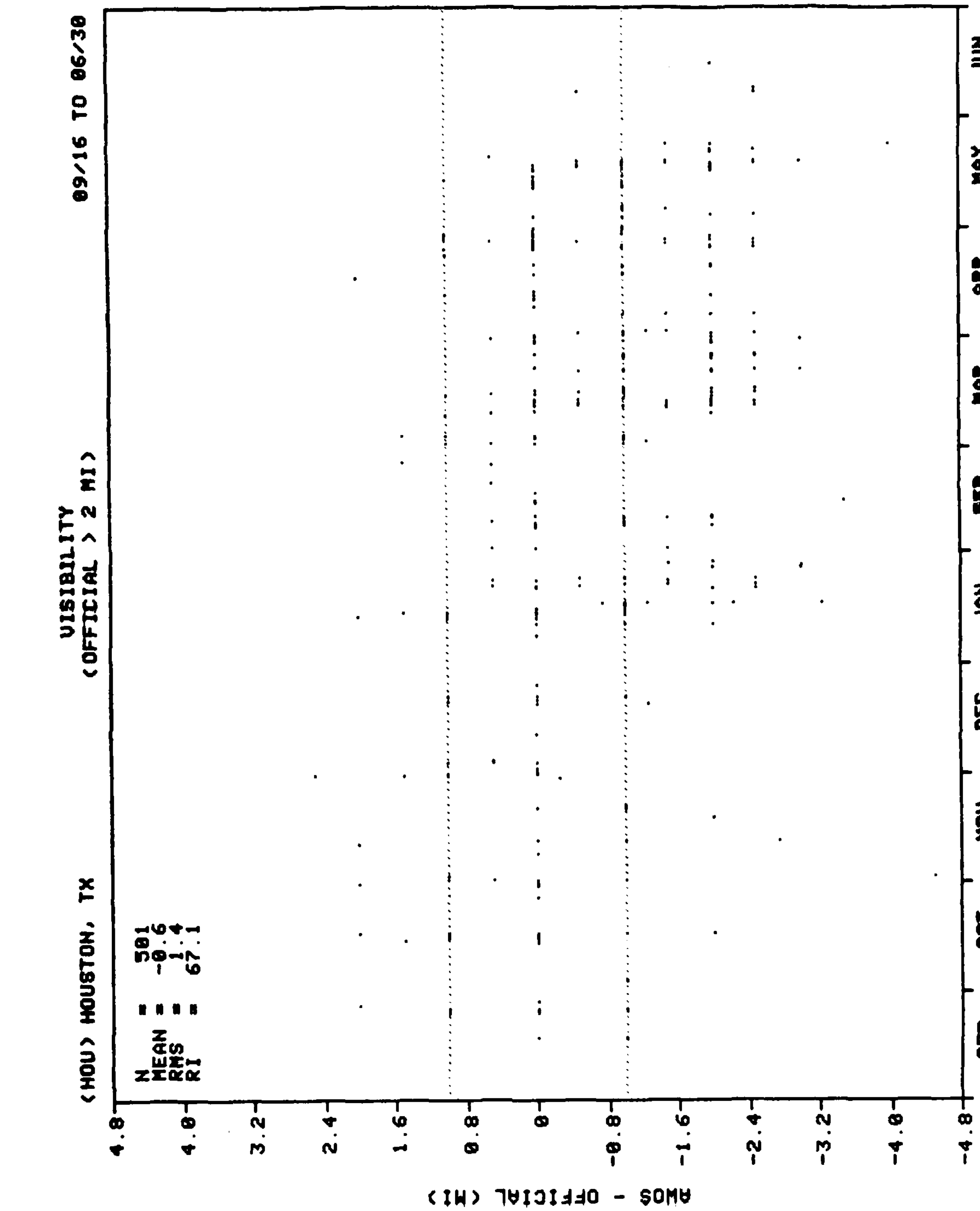
84-20-D-2a


(HOU) HOUSTON, TX
CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/16 TO 06/30
N = 603
MEAN = 498.
RMS = 1189.
RI = 68.3
4800
4000
3200
2400
1600
800
0
-800
-1600
-2400
-3200
-4000
-4800
AWOS - OFFICIAL (FT)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

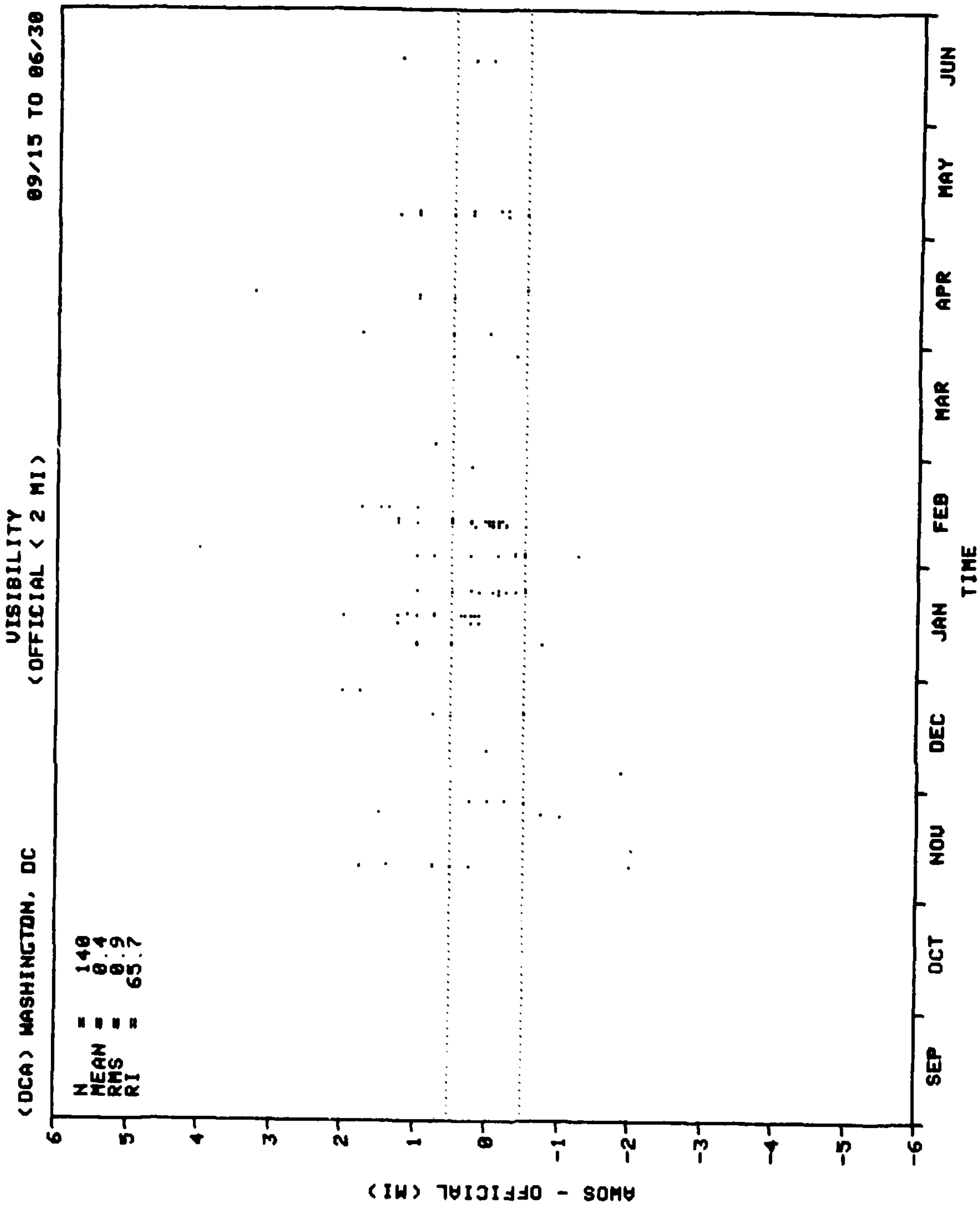
84-20-D-2b


(DCA) WASHINGTON, DC
VISIBILITY
(OFFICIAL > 2 MI)
09/15 TO 06/30
N = 170
MEAN = -0.1
RMS = 1.5
RI = 68.2
AWOS - OFFICIAL (MI)
6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
TIME

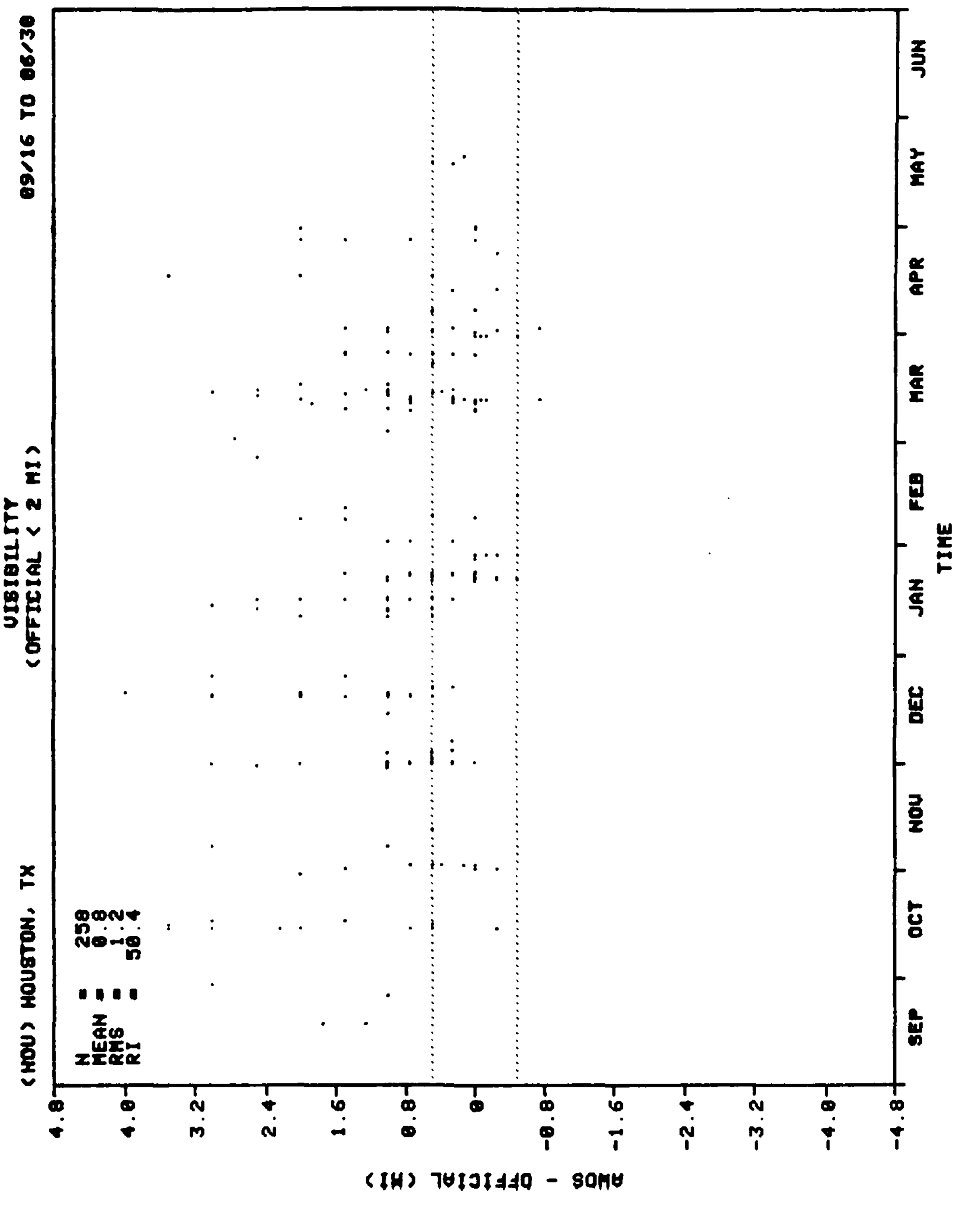
84-20-D-3a


VISIBILITY
(OFFICIAL > 2 MI)
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 501
MEAN = -0.6
RMS = 1.4
RI = 67.1
4.8
4.0
3.2
2.4
1.6
0.8
0
-0.8
-1.6
-2.4
-3.2
-4.0
-4.8
AMOS - OFFICIAL (MI)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

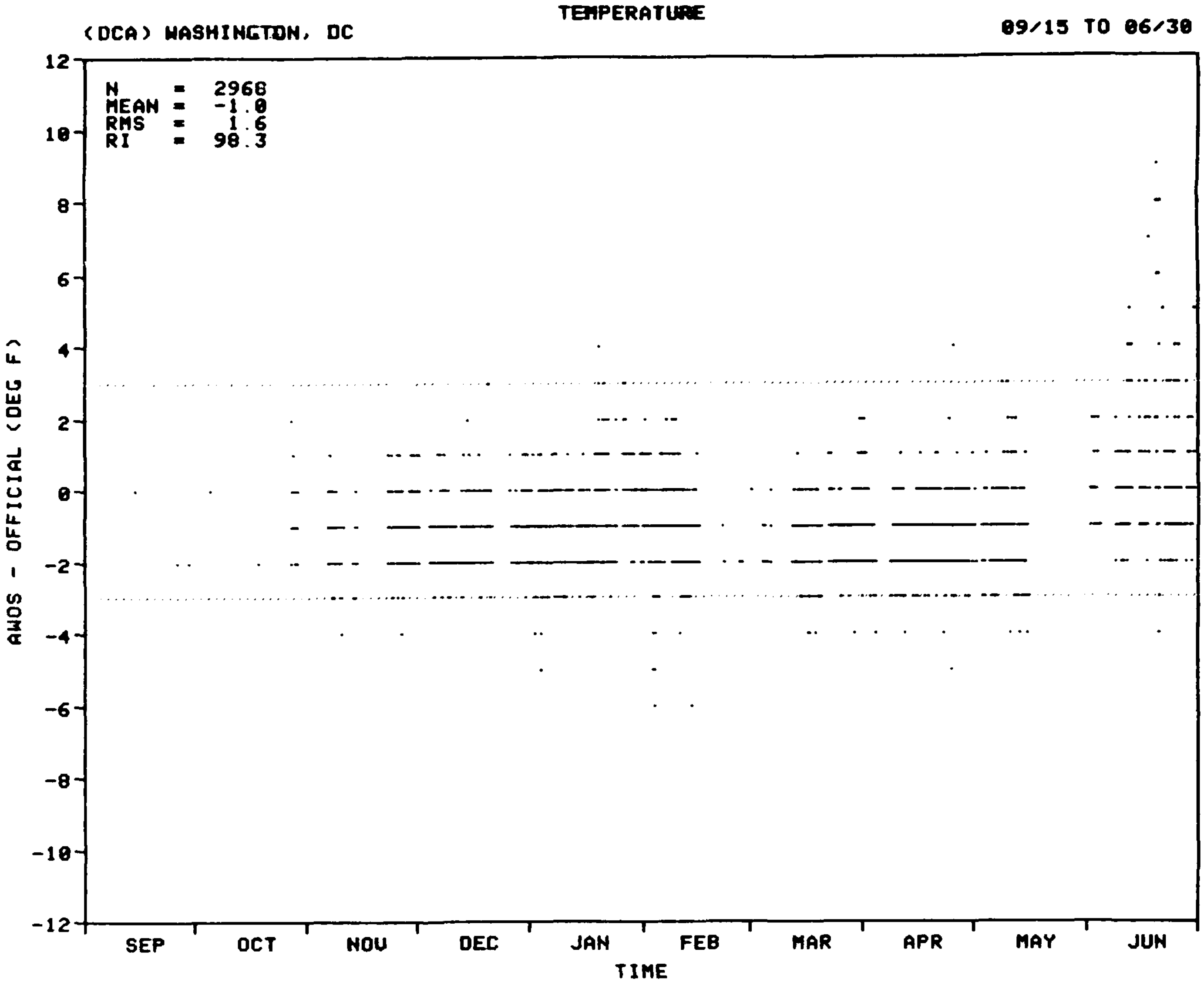
84-20-D-3b


VISIBILITY
(OFFICIAL < 2 MI)
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 140
MEAN = 0.4
RMS = 0.9
RI = 65.7
AMOS - OFFICIAL (MI)
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
TIME
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN

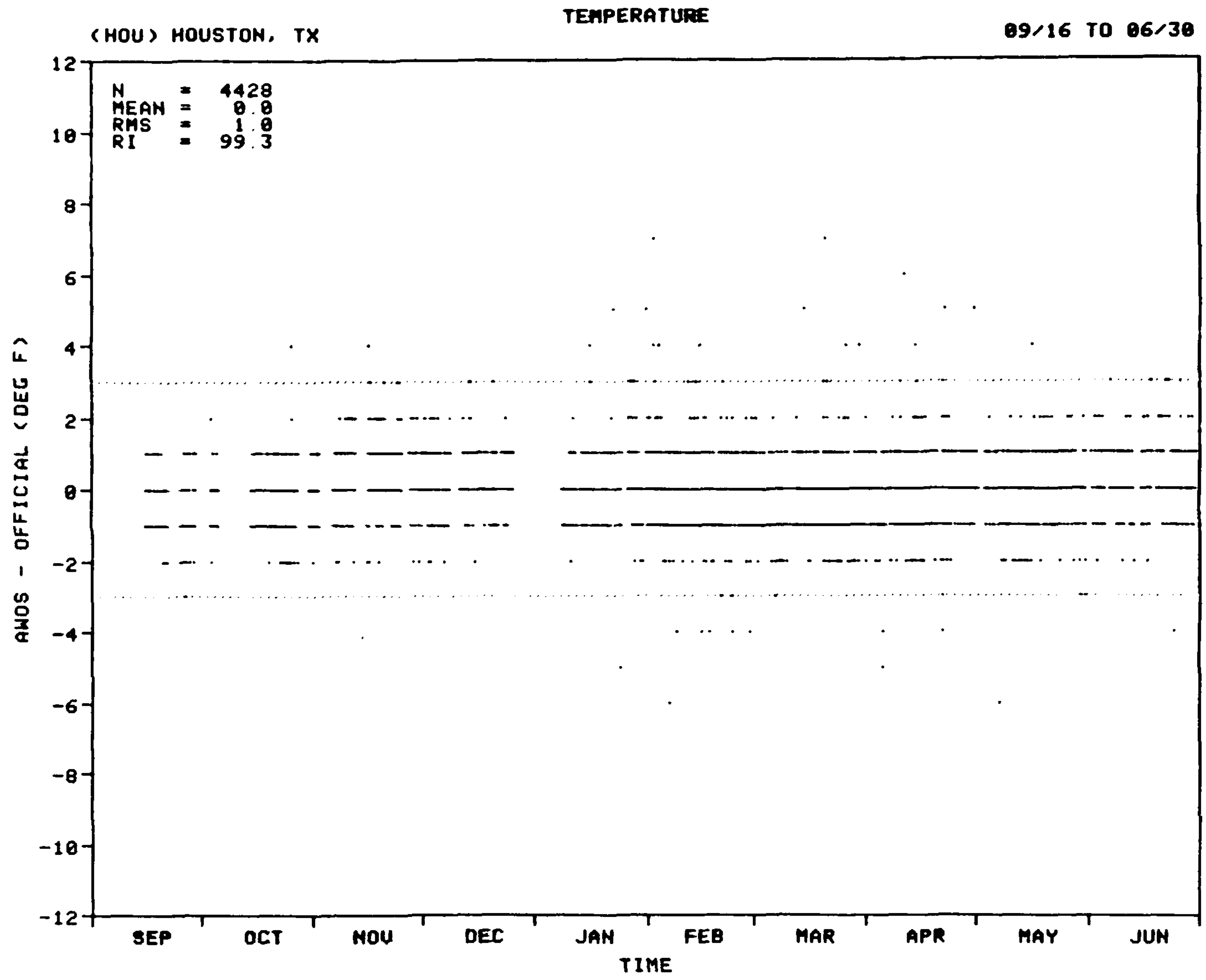
84-20-D-4a


(HOU) HOUSTON, TX
VISIBILITY
(OFFICIAL < 2 MI)
09/16 TO 06/30
N = 258
MEAN = 0.8
RMS = 1.2
RI = 50.4
4.8
4.0
3.2
2.4
1.6
0.8
0
-0.8
-1.6
-2.4
-3.2
-4.0
-4.8
AWOS - OFFICIAL (MI)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-4b

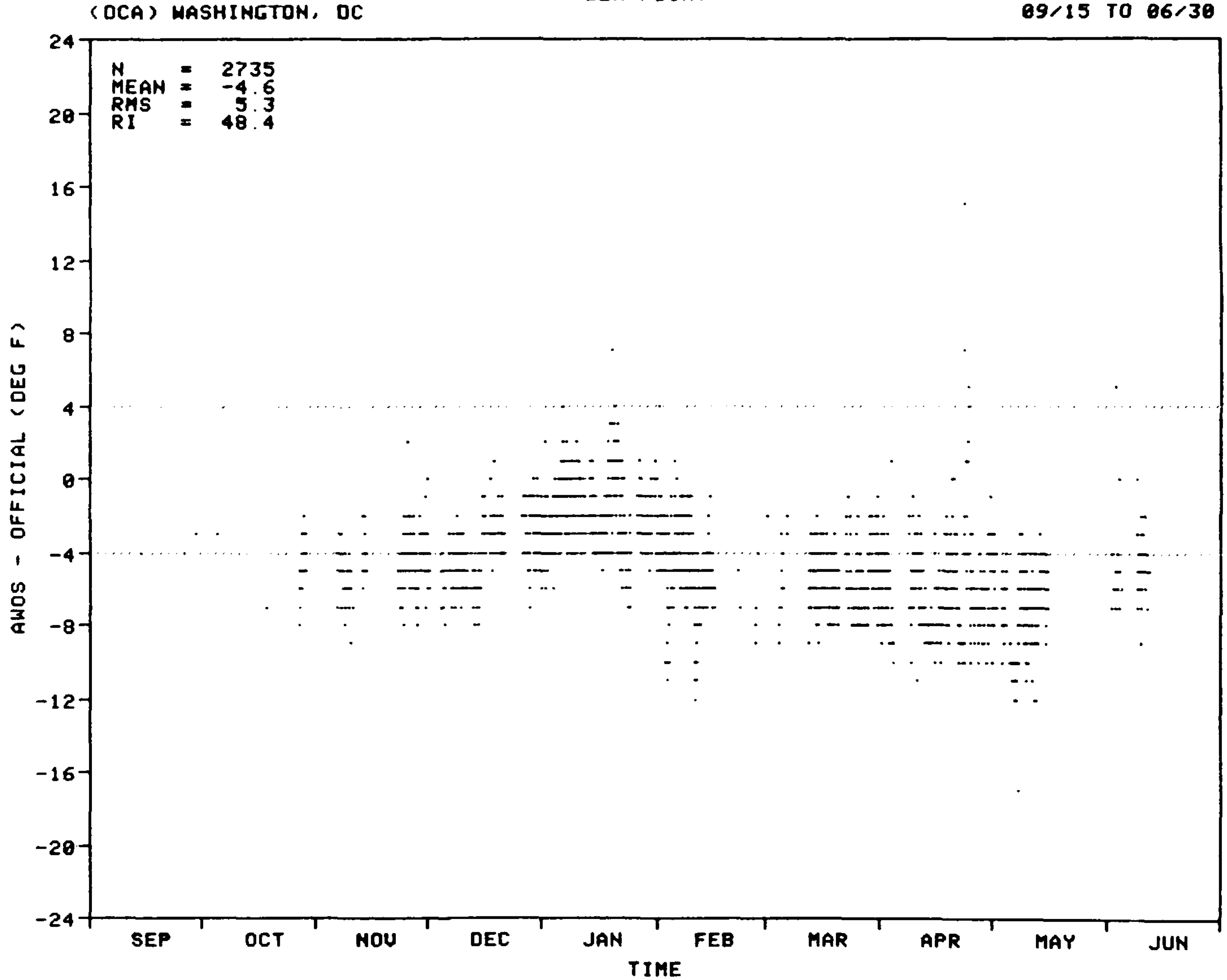

TEMPERATURE
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2968
MEAN = -1.0
RMS = 1.6
RI = 98.3
AWOS - OFFICIAL (DEG F)
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-5a


TEMPERATURE
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4428
MEAN = 0.0
RMS = 1.0
RI = 99.3
AWOS - OFFICIAL (DEG F)
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-5b

DEW POINT



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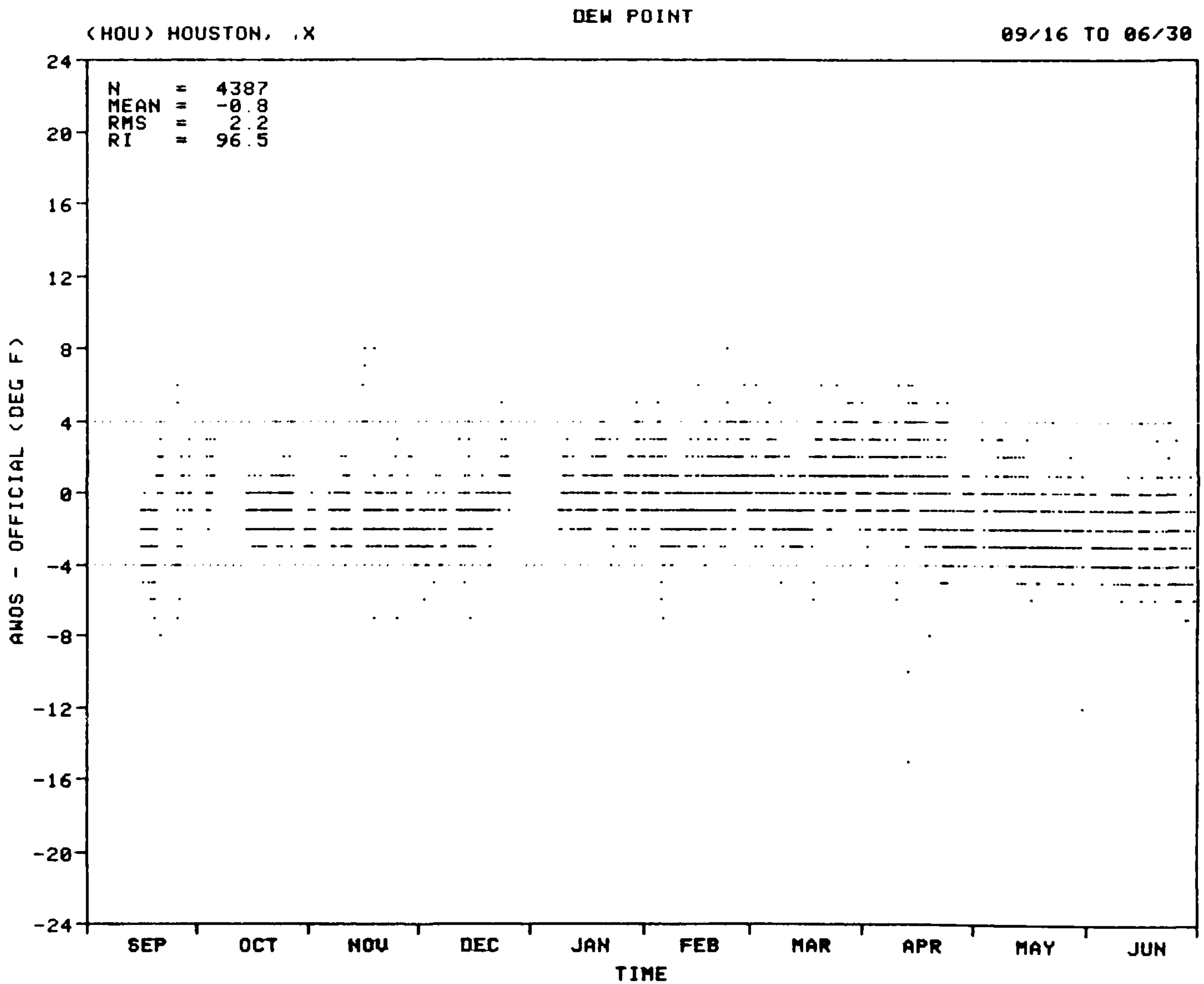
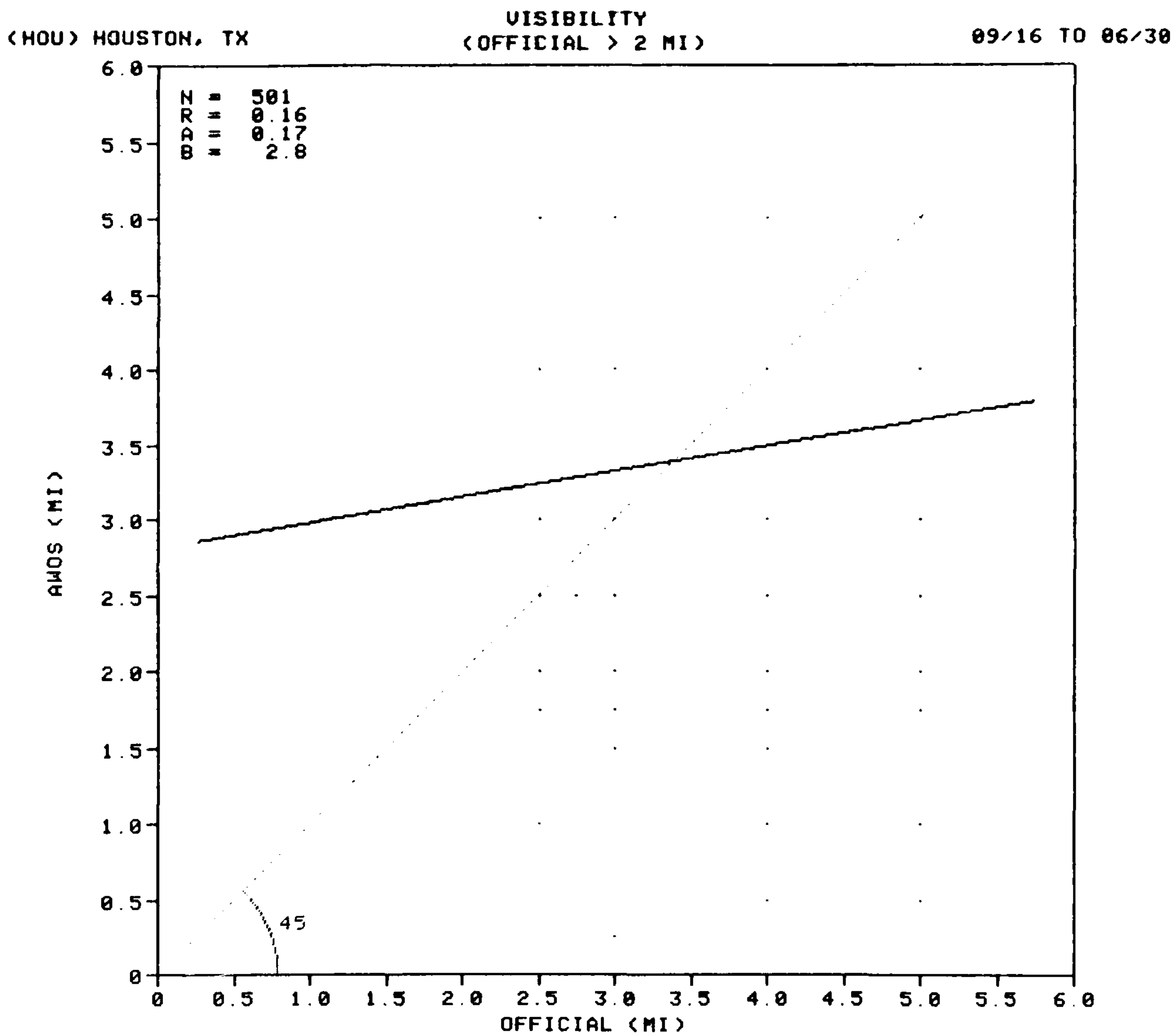


DEW POINT
(HOU) HOUSTON, .X
09/16 TO 06/30
N = 4387
MEAN = -0.8
RMS = 2.2
RI = 96.5
AWOS - OFFICIAL (DEG F)
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-6b



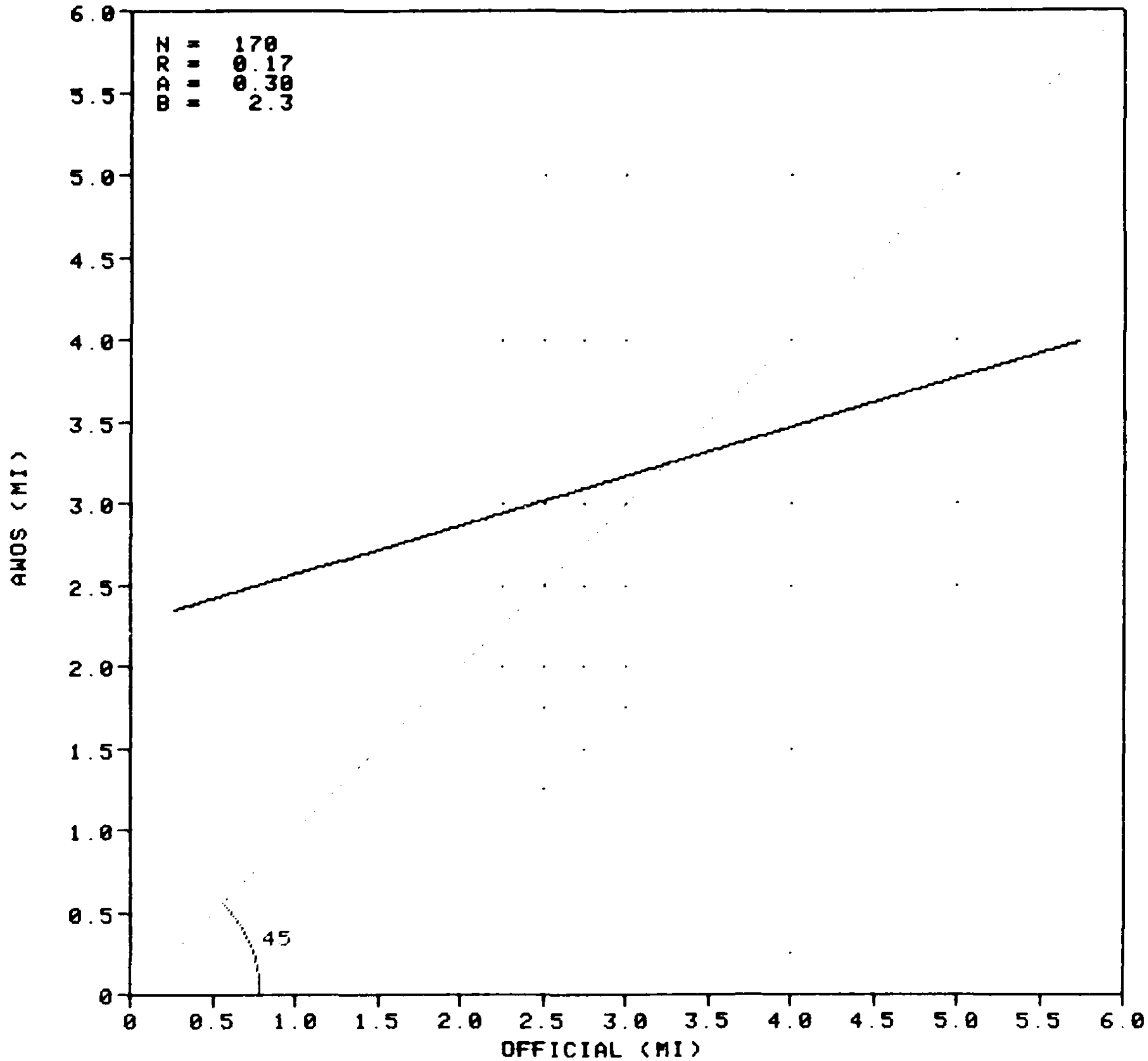
(HOU) HOUSTON, TX
VISIBILITY
(OFFICIAL > 2 MI)
09/16 TO 06/30
N = 501
R = 0.16
A = 0.17
B = 2.8
45
AWOS (MI)
OFFICIAL (MI)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

84-20-D-13D

(DCA) WASHINGTON, DC

VISIBILITY
(OFFICIAL > 2 MI)

09/15 TO 06/30



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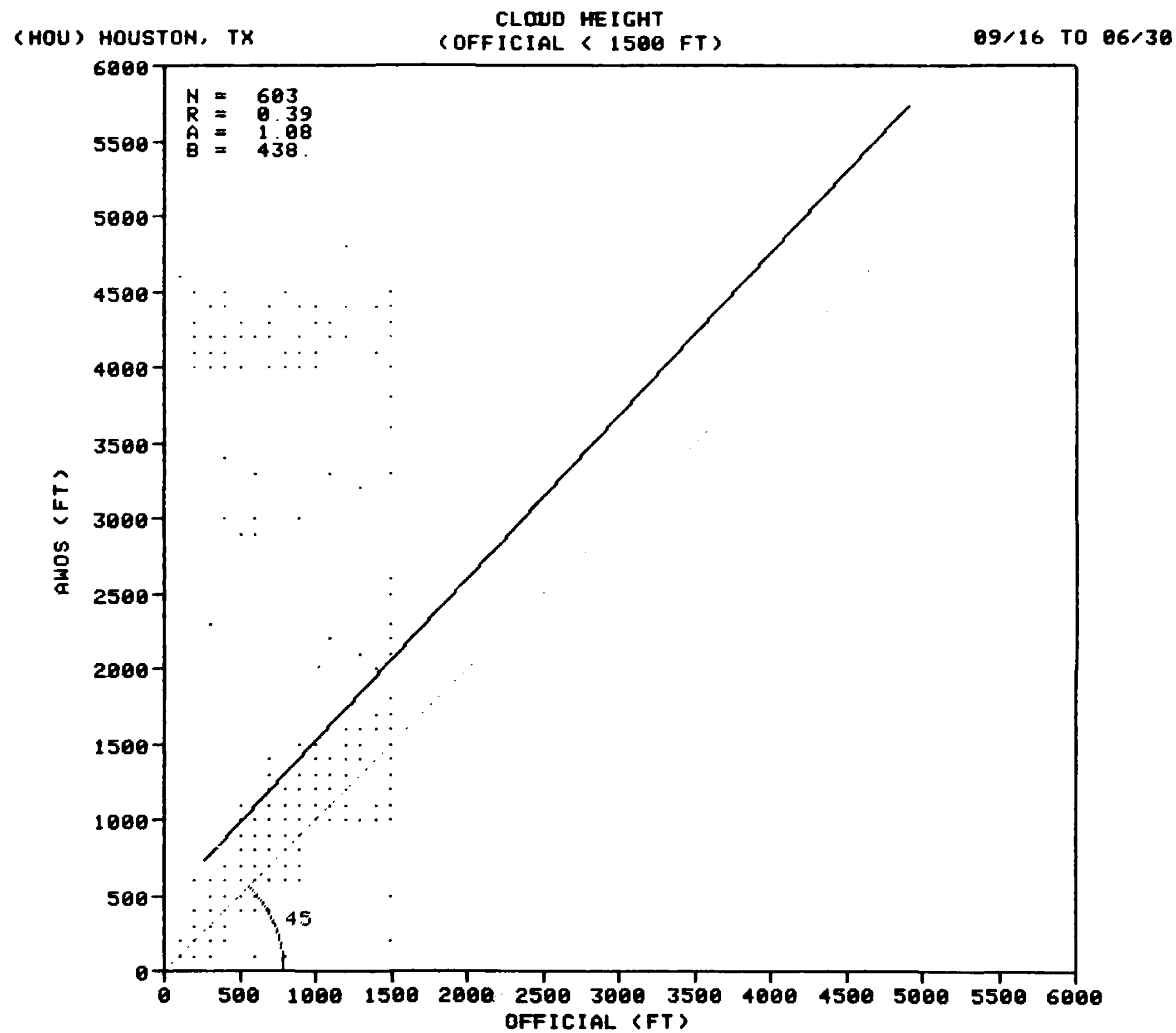
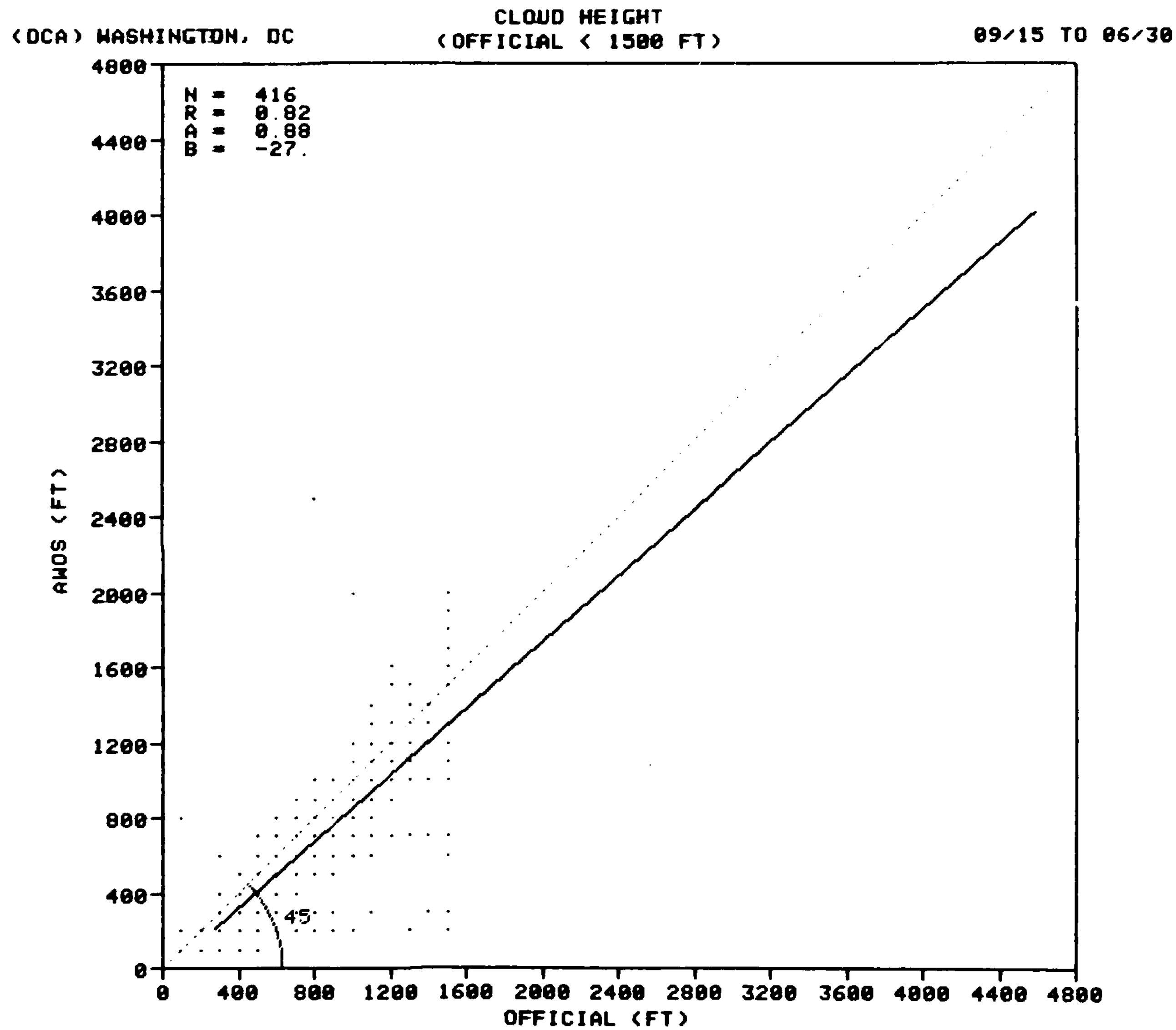

(HOU) HOUSTON, TX
CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/16 TO 06/30
N = 603
R = 0.39
A = 1.08
B = 438
45
AWOS (FT)
OFFICIAL (FT)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000

84-20-D-12b

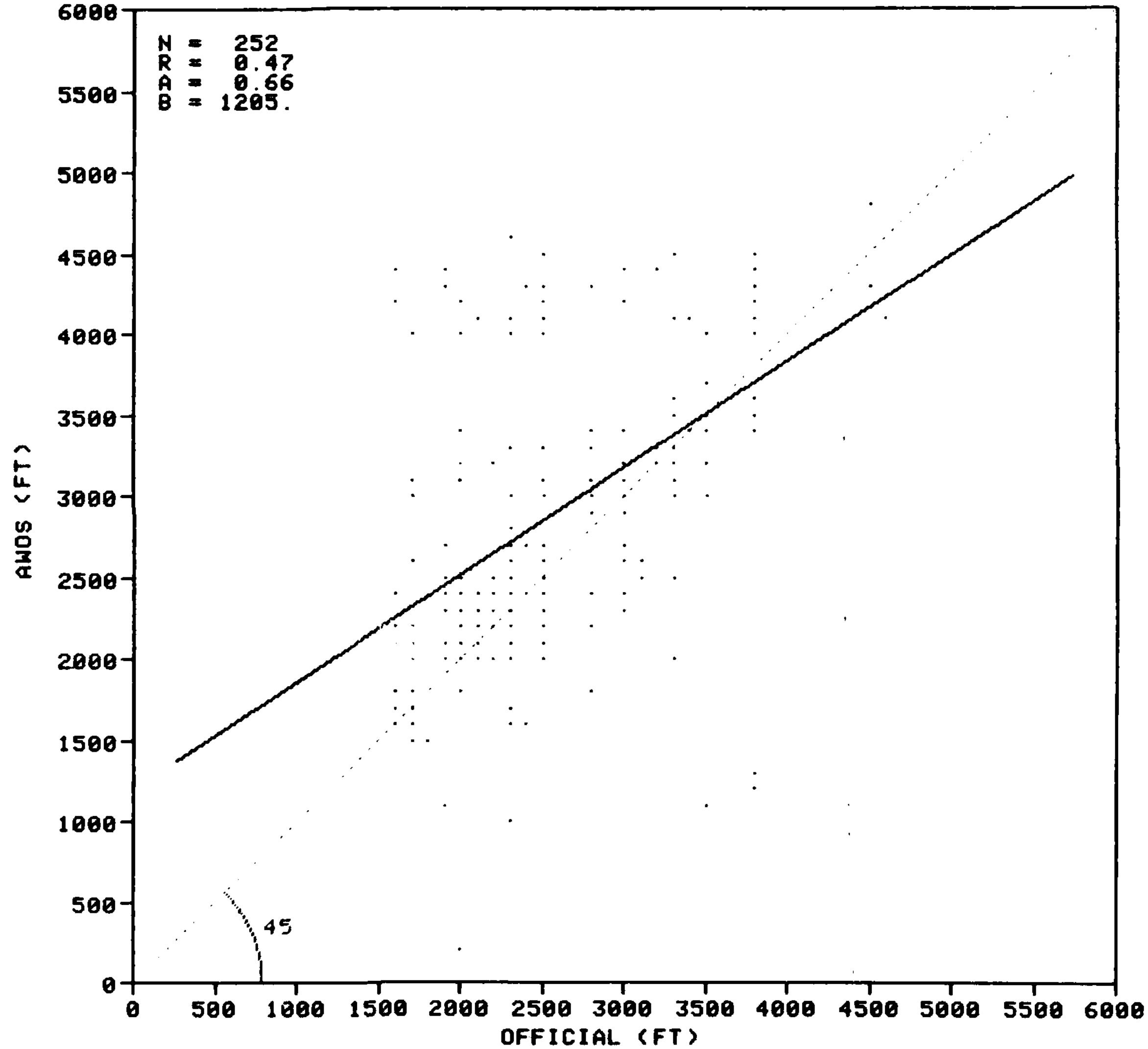

(DCA) WASHINGTON, DC
CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/15 TO 06/30
N = 416
R = 0.82
A = 0.88
B = -27.
AWOS (FT)
OFFICIAL (FT)
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
45°

84-20-D-12a

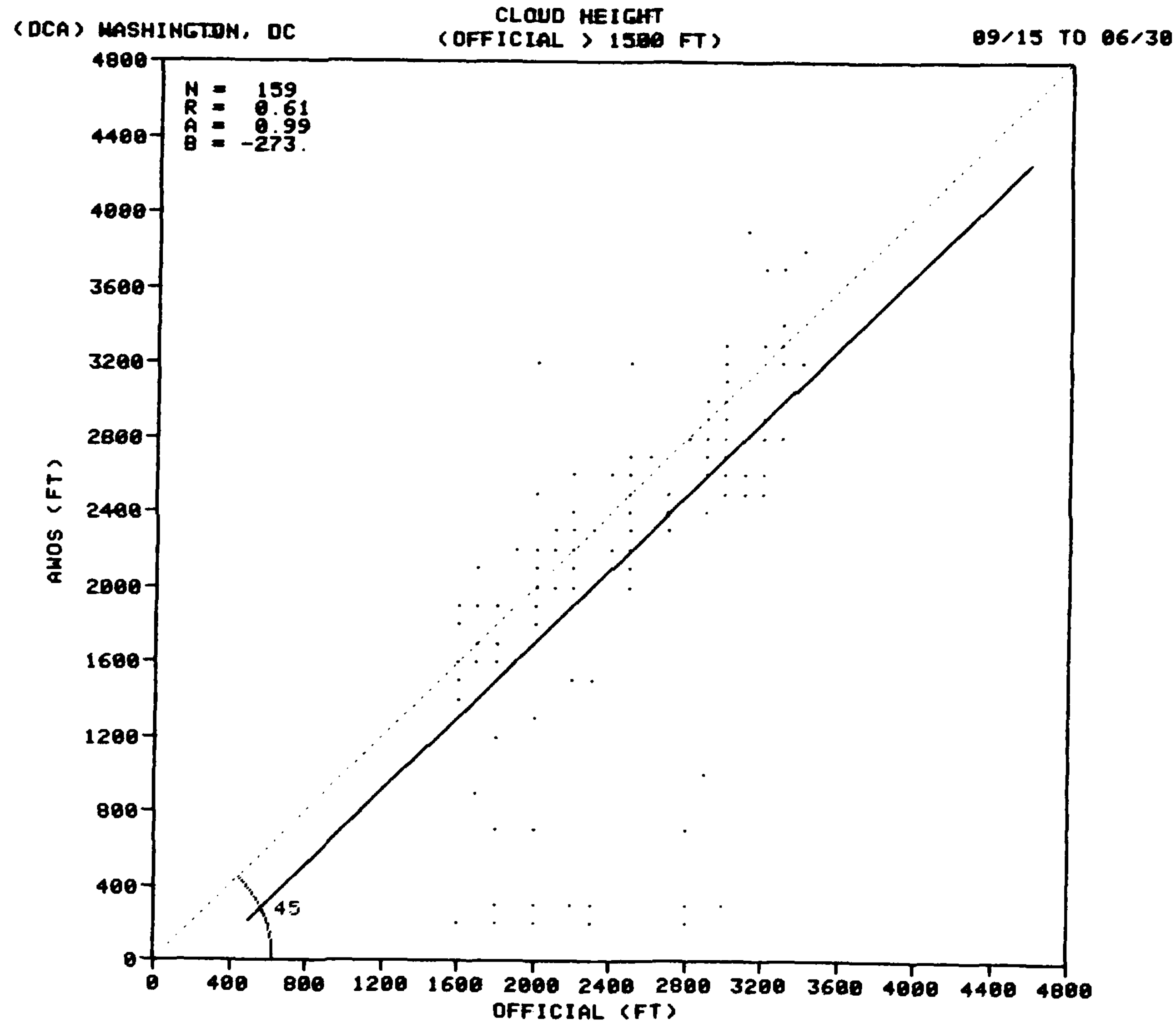
(HOU) HOUSTON, TX

CLOUD HEIGHT
(OFFICIAL > 1500 FT)

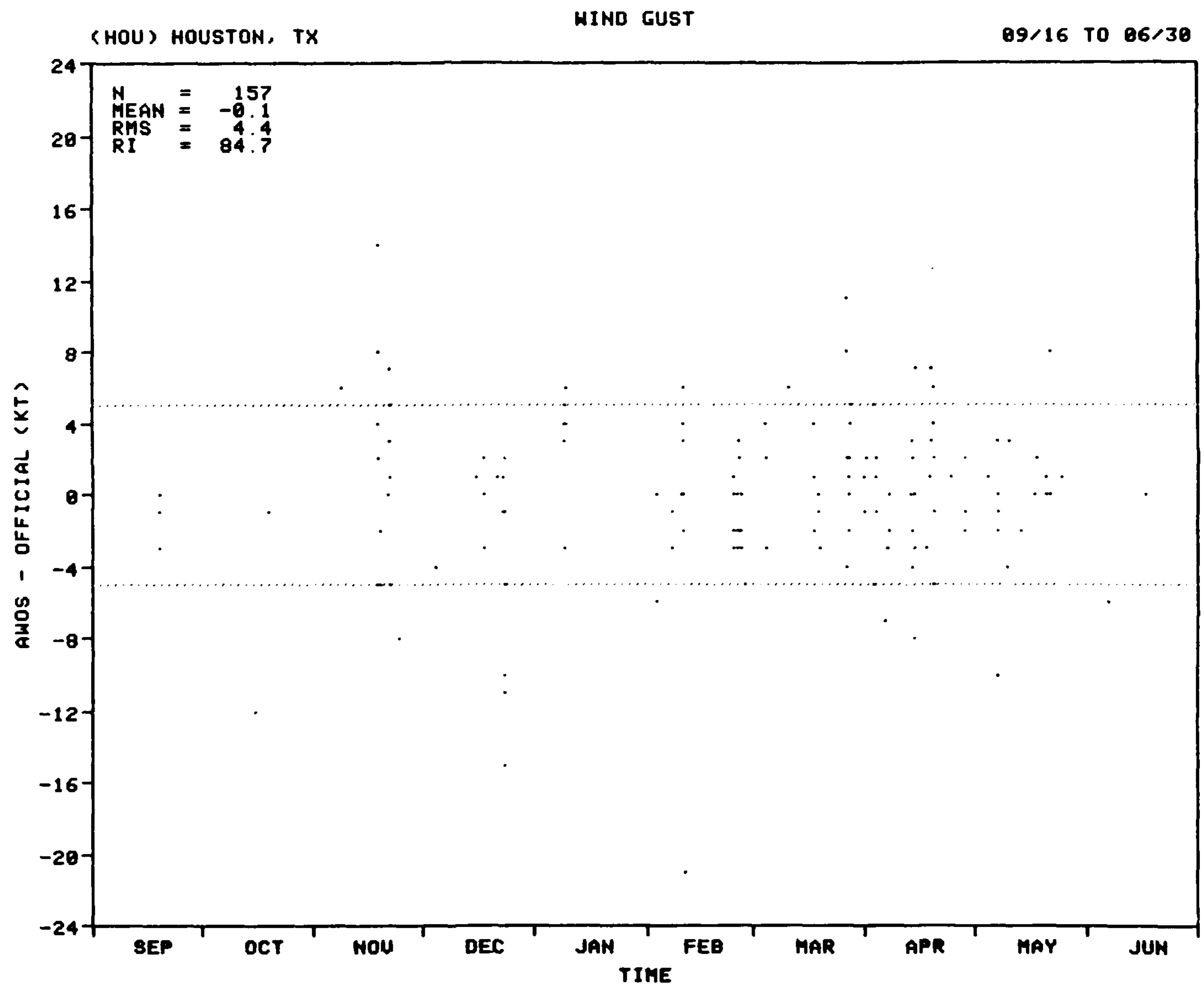
09/16 TO 06/30



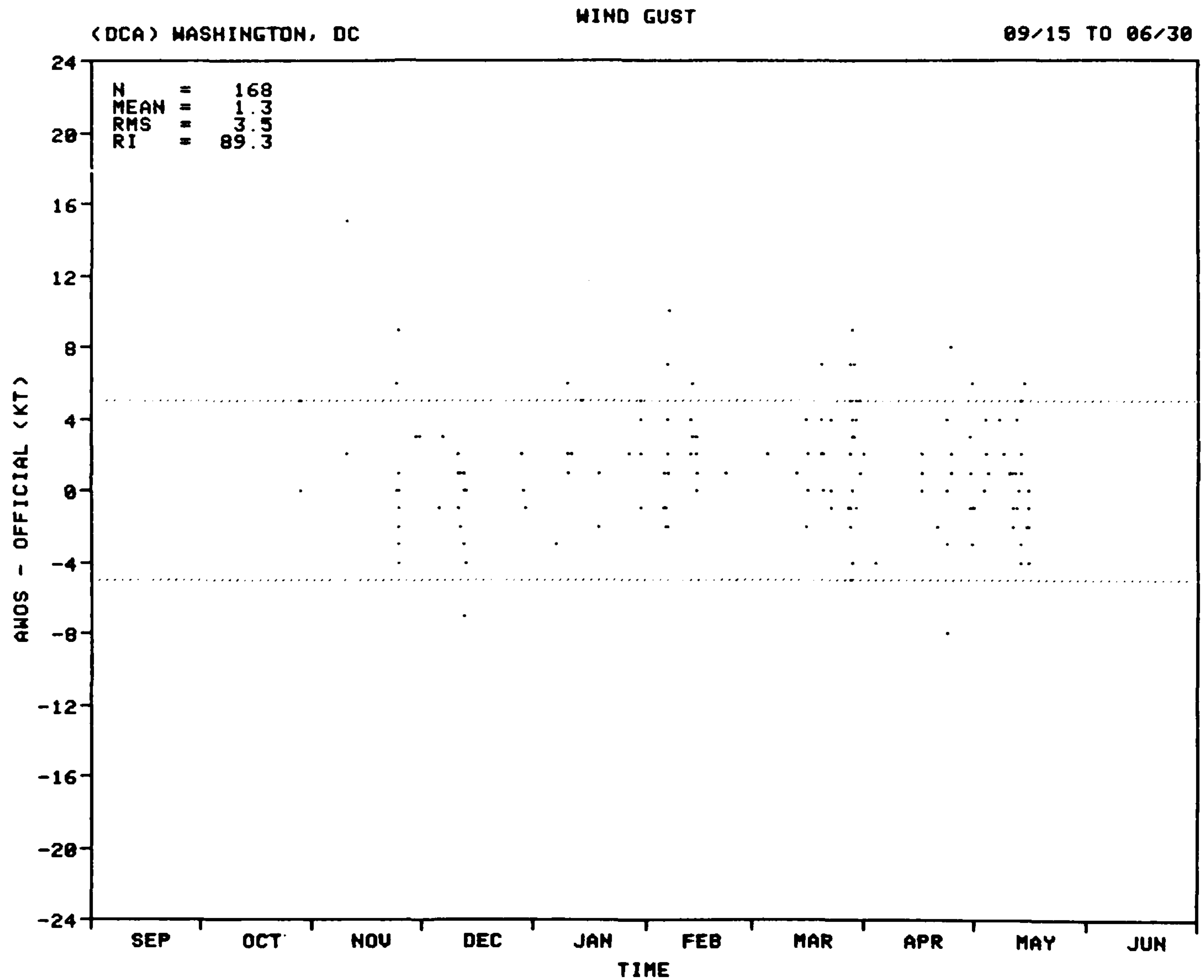
84-20-D-11b


(DCA) WASHINGTON, DC
CLOUD HEIGHT
(OFFICIAL > 1500 FT)
09/15 TO 06/30
N = 159
R = 0.61
A = 0.99
B = -273.
45
AWOS (FT)
OFFICIAL (FT)
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800

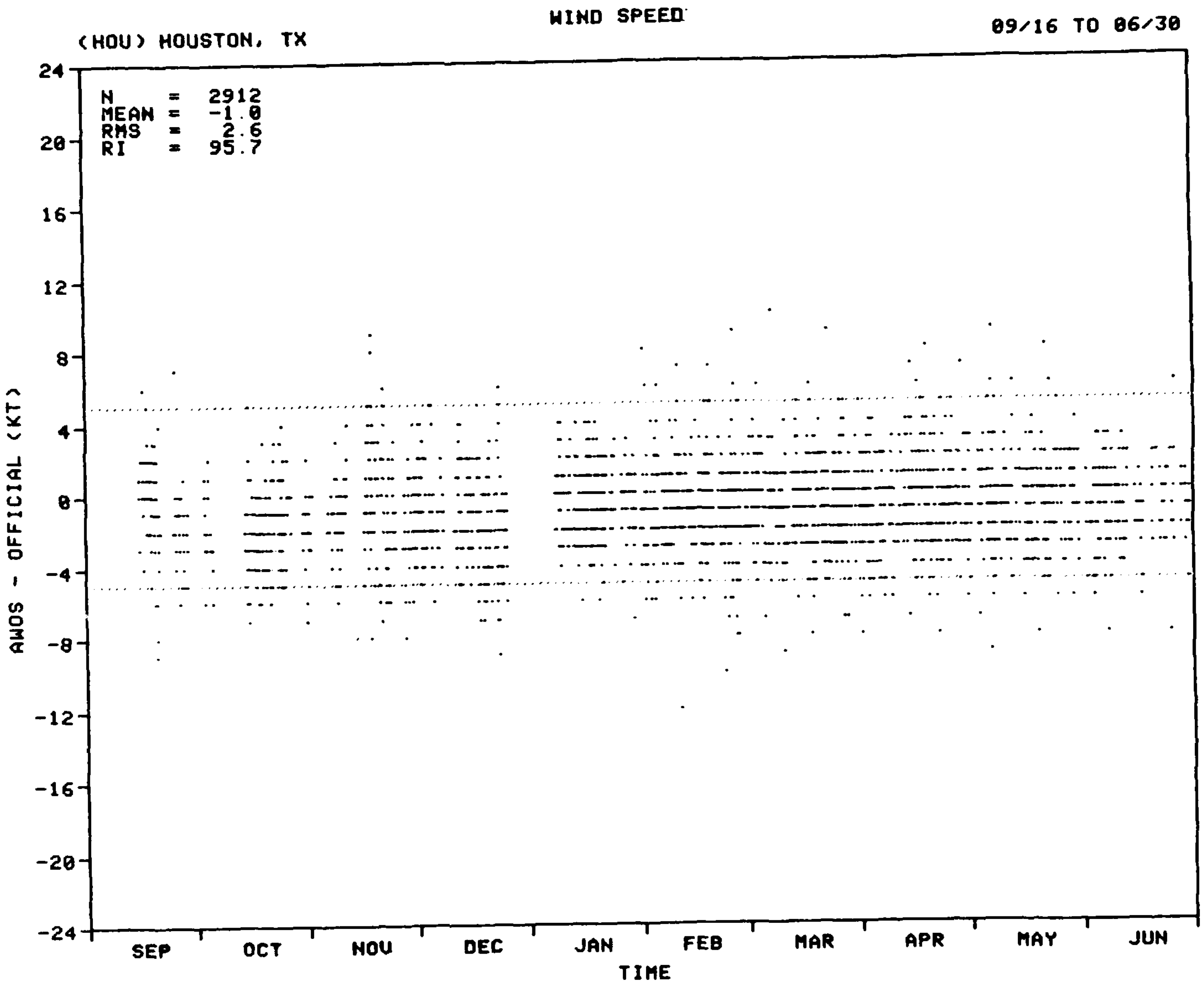
84-20-D-11a


WIND GUST
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 157
MEAN = -0.1
RMS = 4.4
RI = 84.7
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
AWOS - OFFICIAL (KT)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

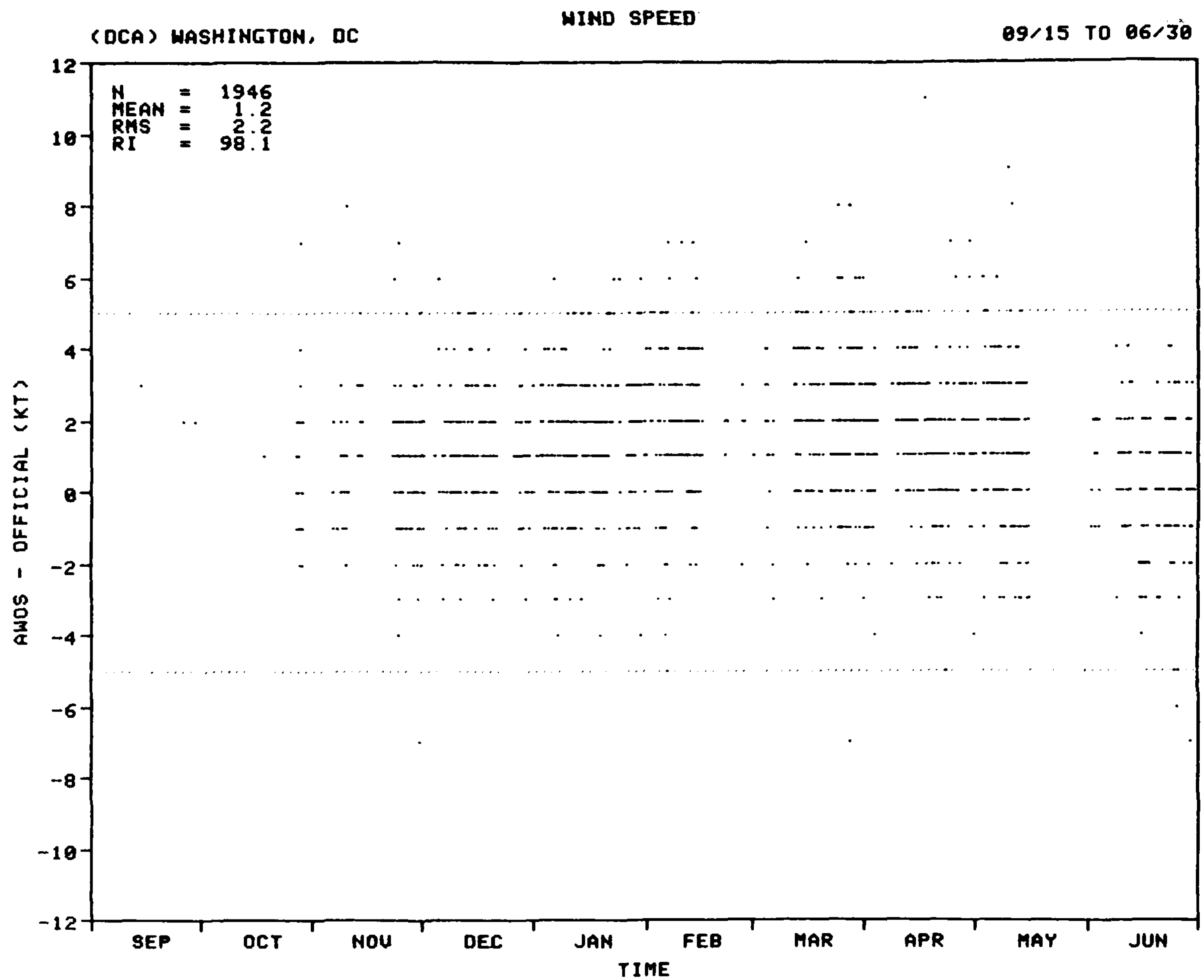
84-20-D-10b


WIND GUST
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 168
MEAN = 1.3
RMS = 3.5
RI = 89.3
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
AWOS - OFFICIAL (KT)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

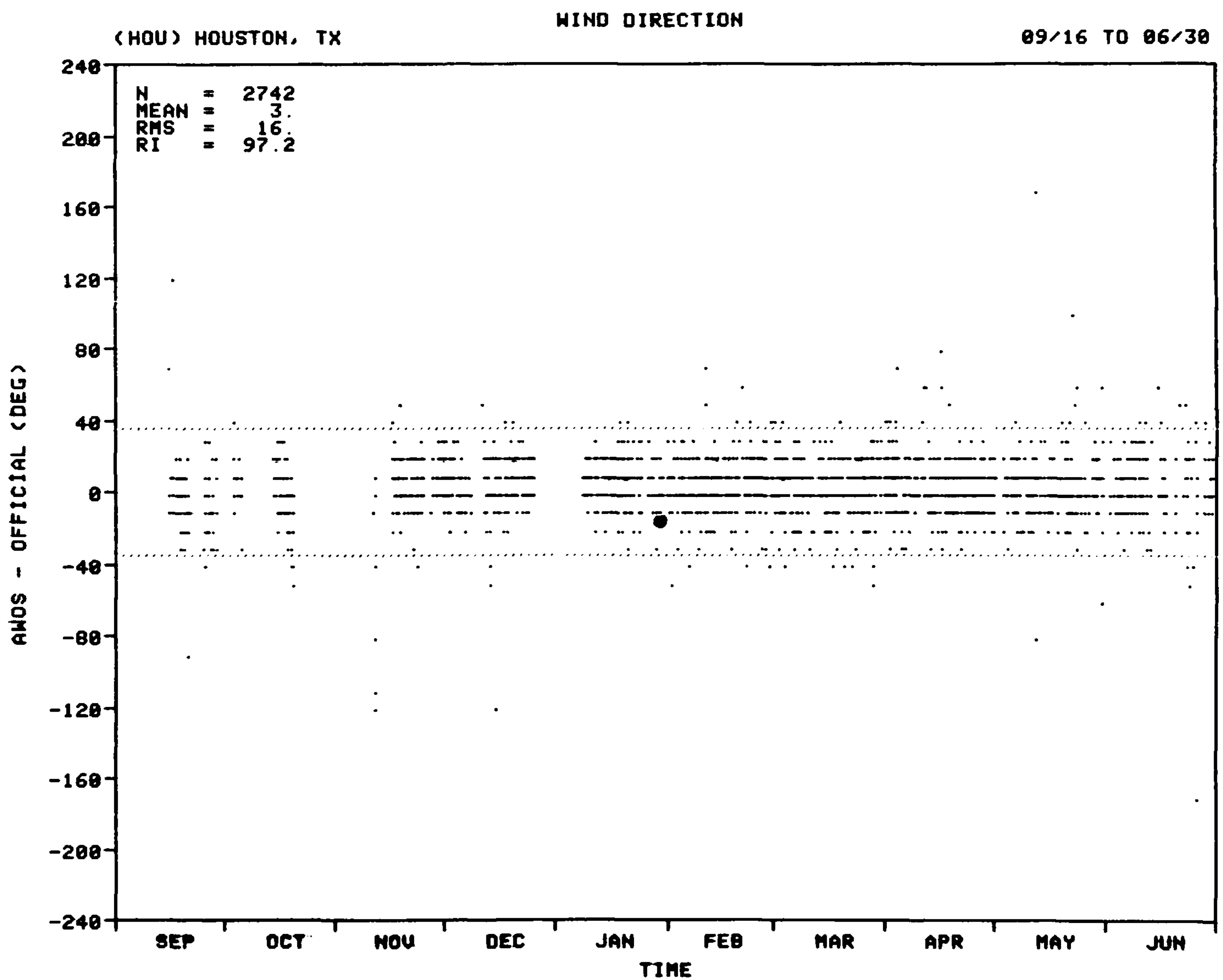
84-20-D-10a

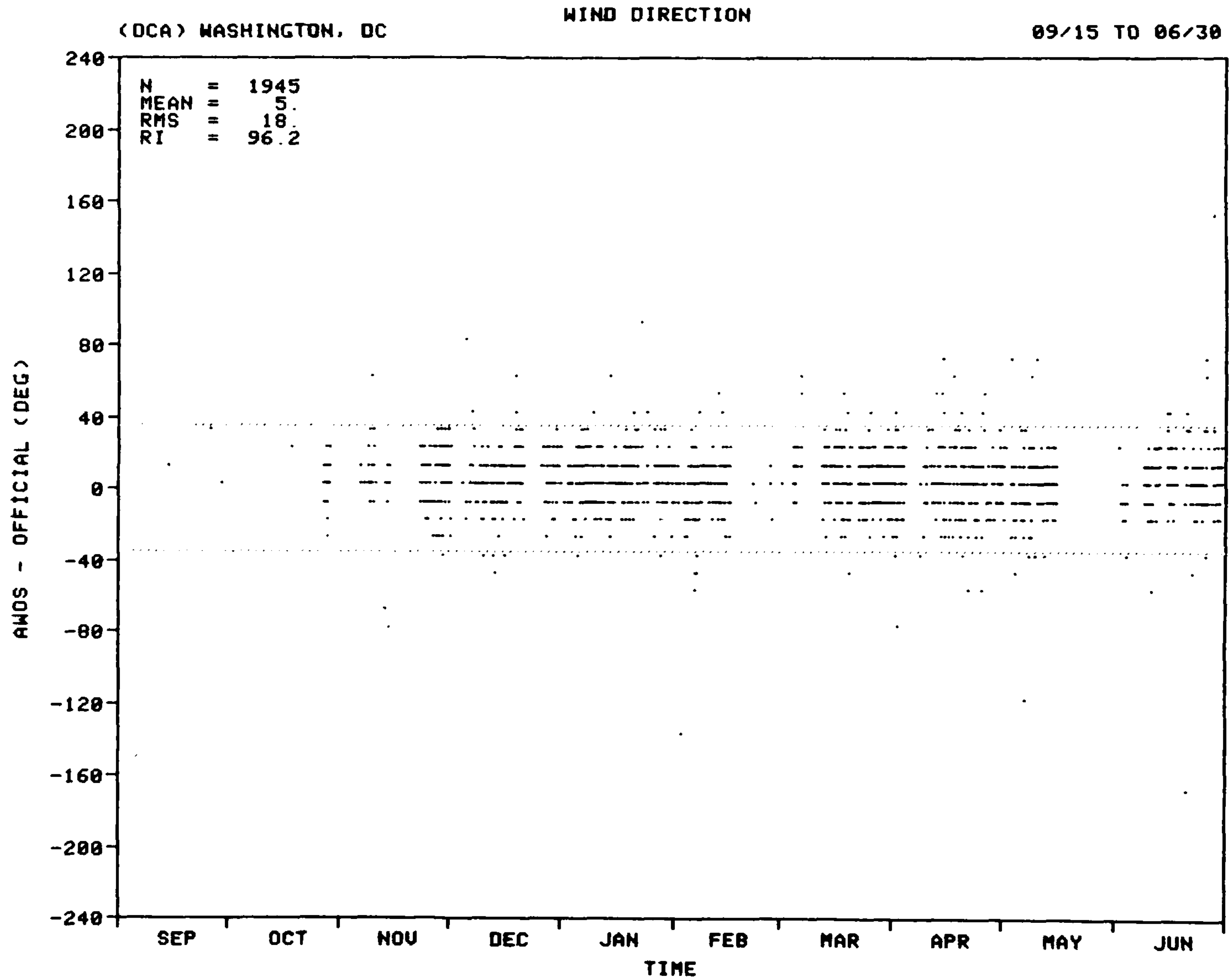

WIND SPEED
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 2912
MEAN = -1.0
RMS = 2.6
RI = 95.7
AWOS - OFFICIAL (KT)
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-9b

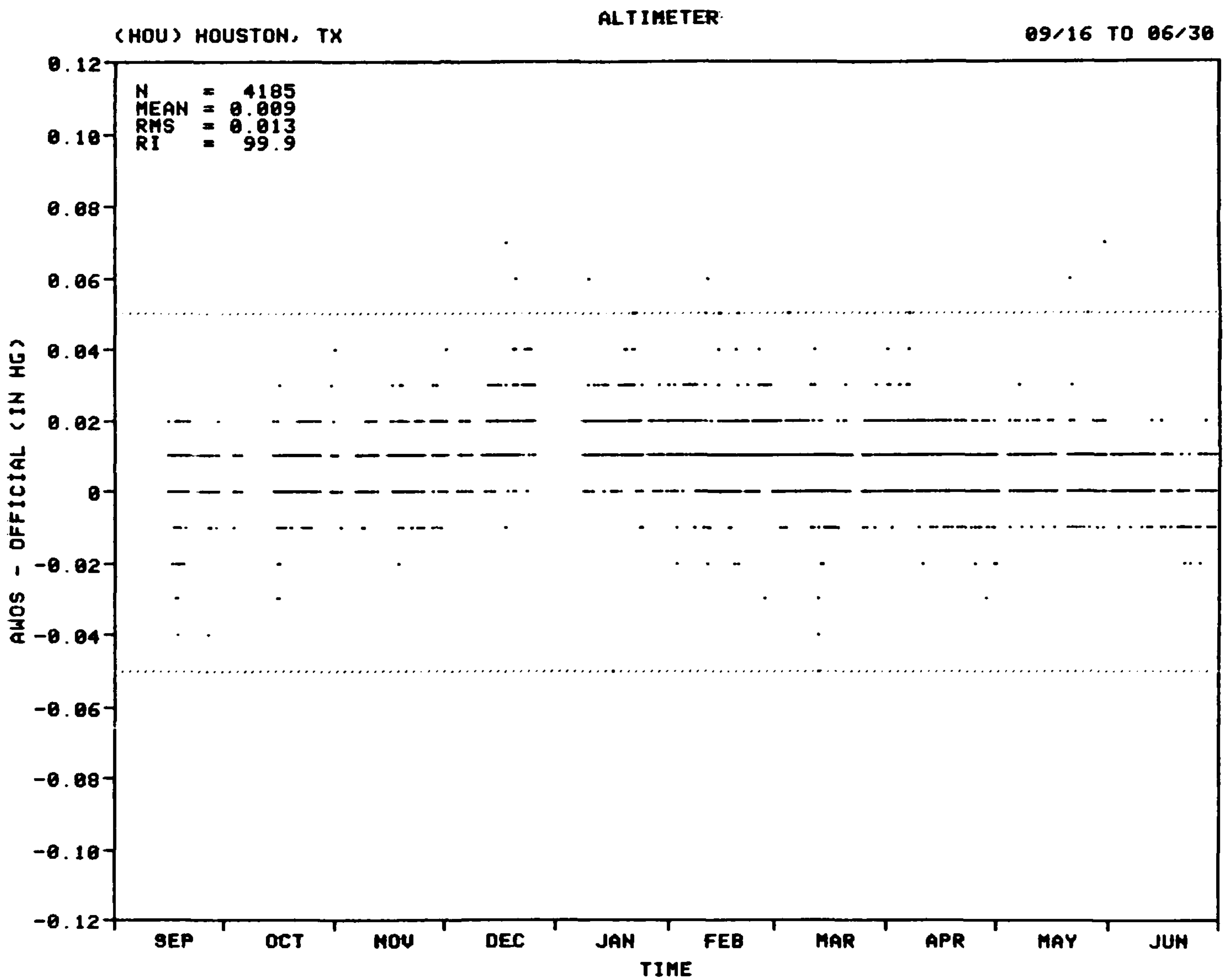

WIND SPEED
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 1946
MEAN = 1.2
RMS = 2.2
RI = 98.1
AWOS - OFFICIAL (KT)
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-9a

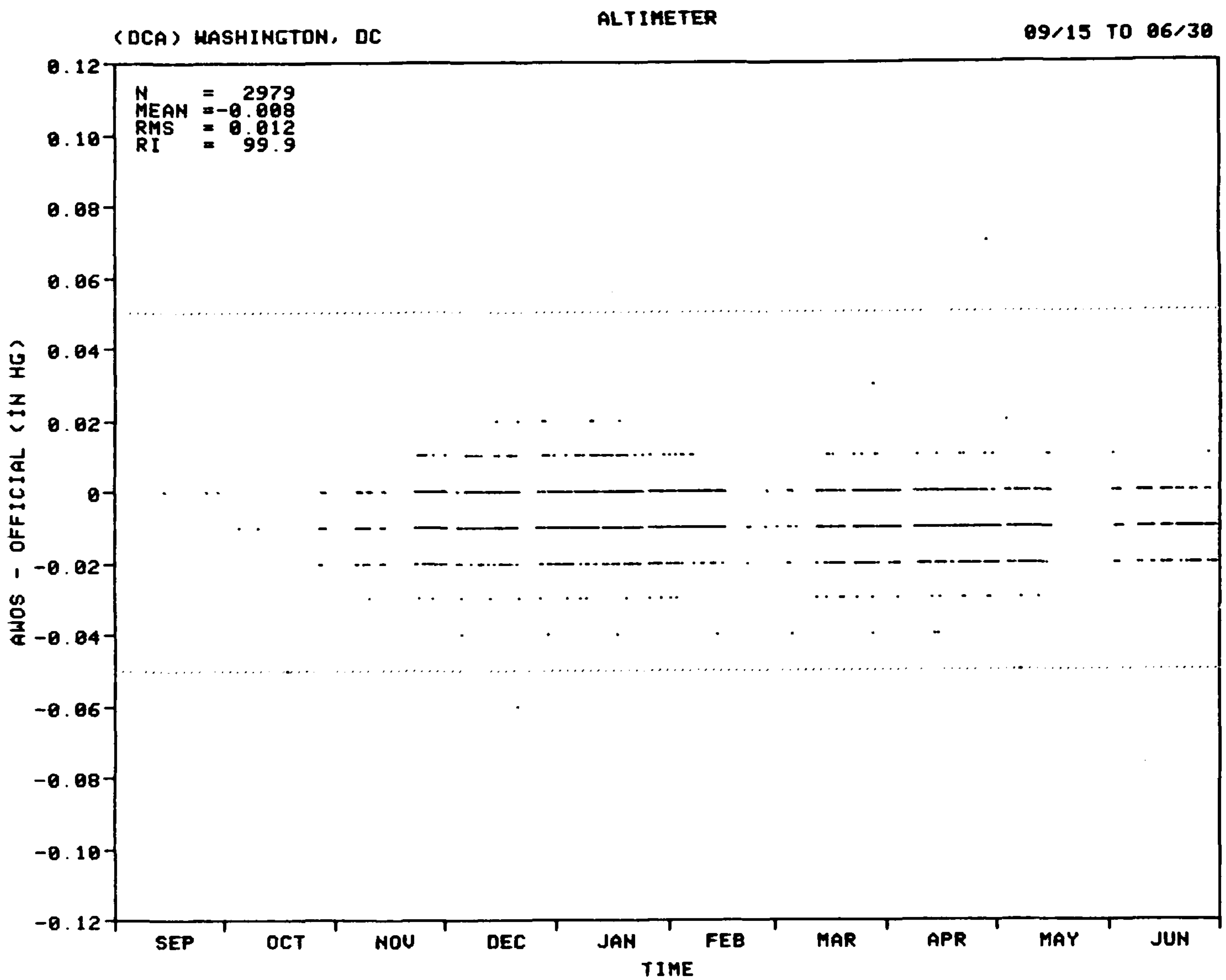

WIND DIRECTION
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 2742
MEAN = 3.
RMS = 16.
RI = 97.2
AWOS - OFFICIAL (DEG)
240
200
160
120
80
40
0
-40
-80
-120
-160
-200
-240
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME
84-20-D-8b


WIND DIRECTION
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 1945
MEAN = 5.
RMS = 18.
RI = 96.2
240
200
160
120
80
40
0
-40
-80
-120
-160
-200
-240
AWOS - OFFICIAL (DEG)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

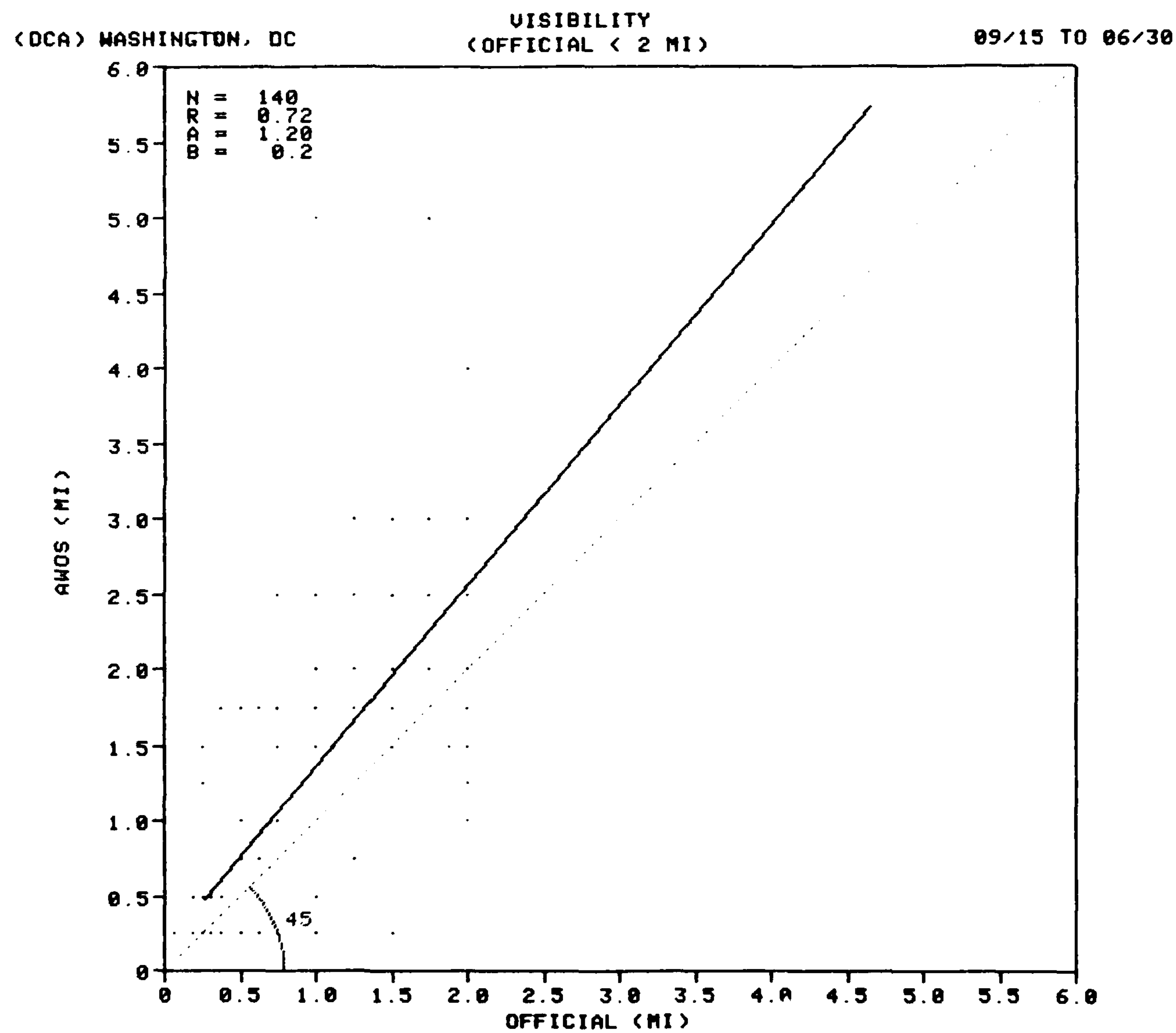
84-20-D-8a


ALTIMETER
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4185
MEAN = 0.009
RMS = 0.013
RI = 99.9
AWOS - OFFICIAL (IN HG)
0.12
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

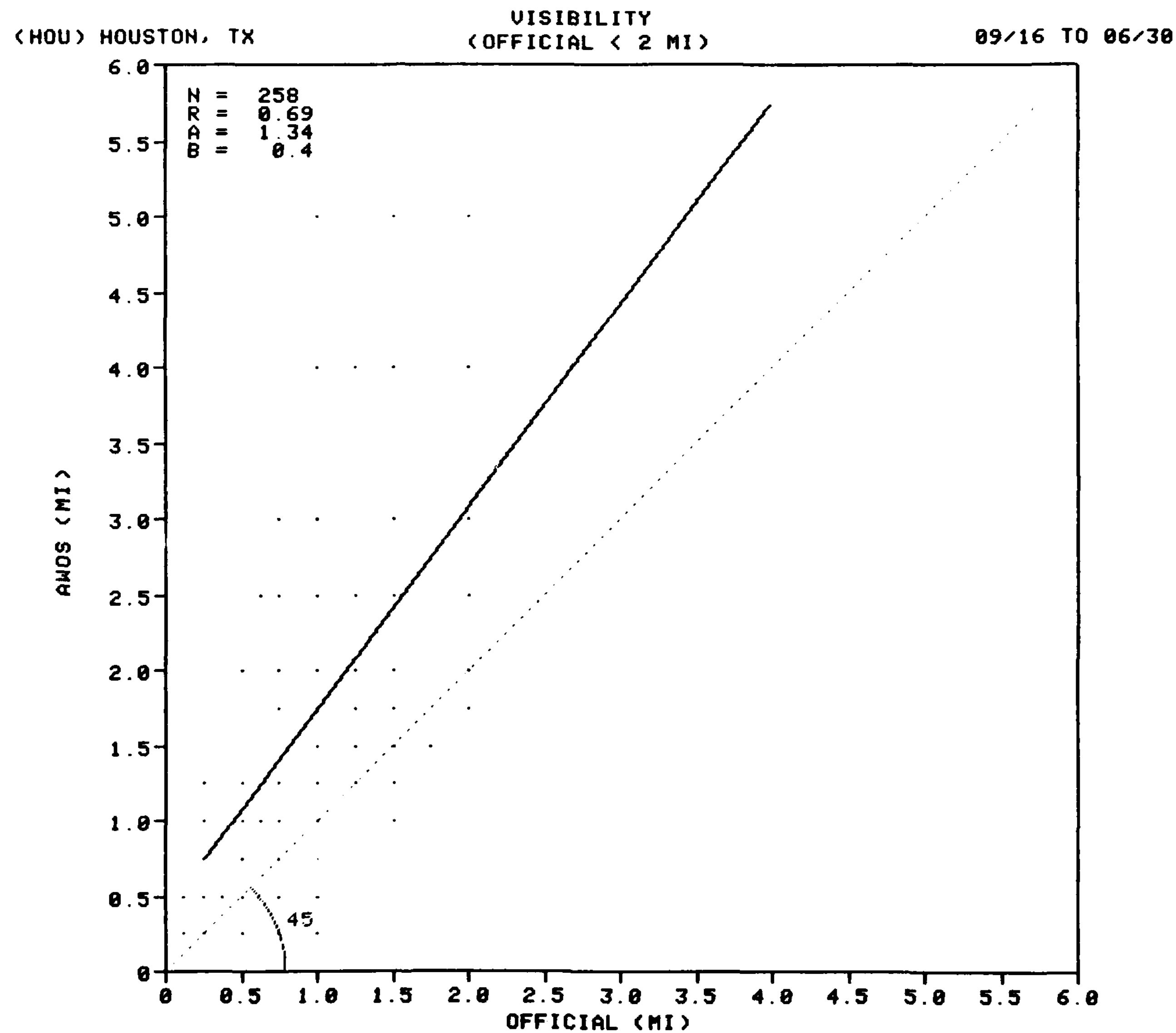
84-20-D-7b


ALTIMETER
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2979
MEAN =-0.008
RMS = 0.012
RI = 99.9
0.12
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
AWOS - OFFICIAL (IN HG)
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
TIME

84-20-D-7a

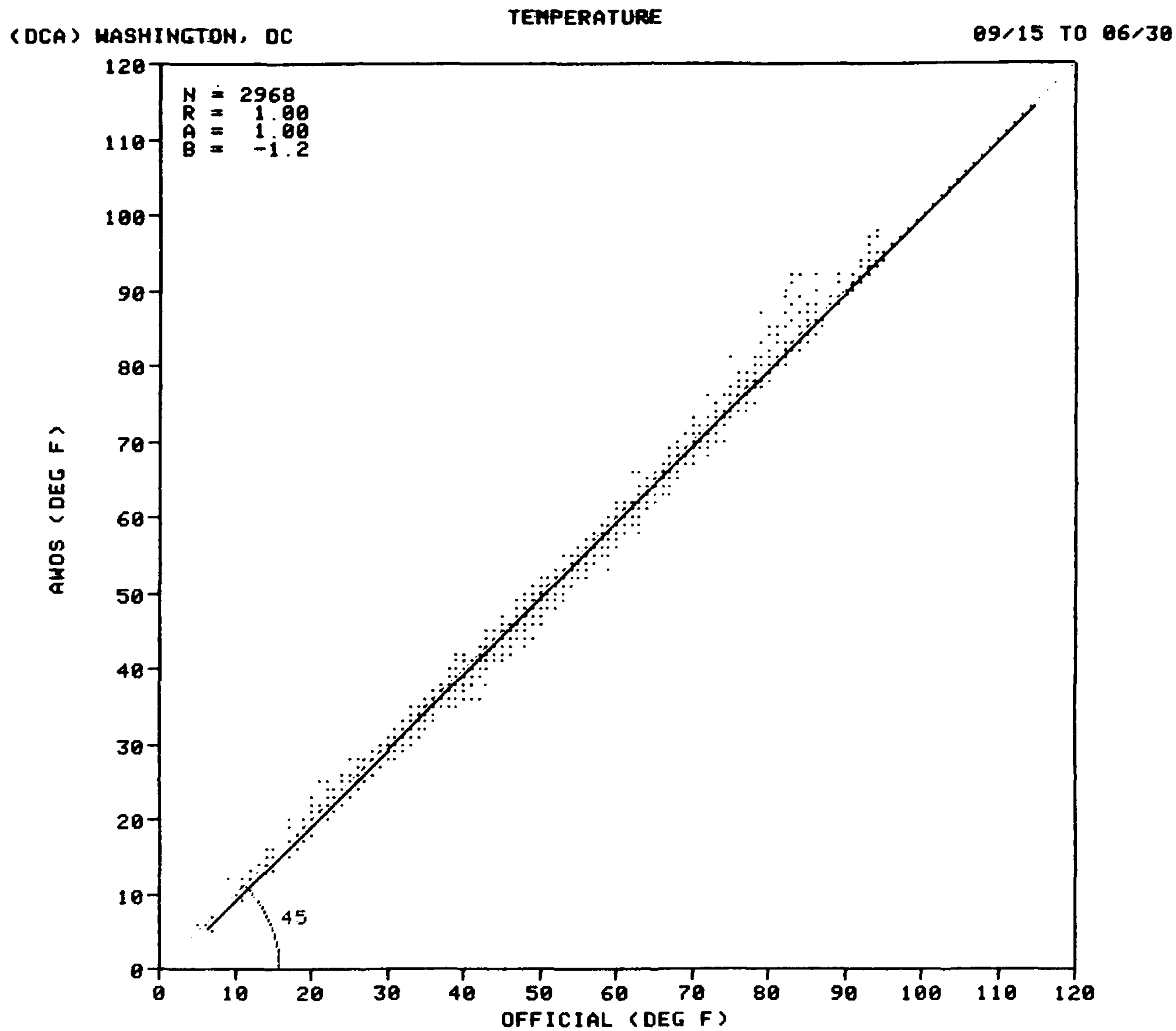

(DCA) WASHINGTON, DC
VISIBILITY
(OFFICIAL < 2 MI)
09/15 TO 06/30
N = 140
R = 0.72
A = 1.20
B = 0.2
45
AWOS (MI)
OFFICIAL (MI)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

84-20-D-14a



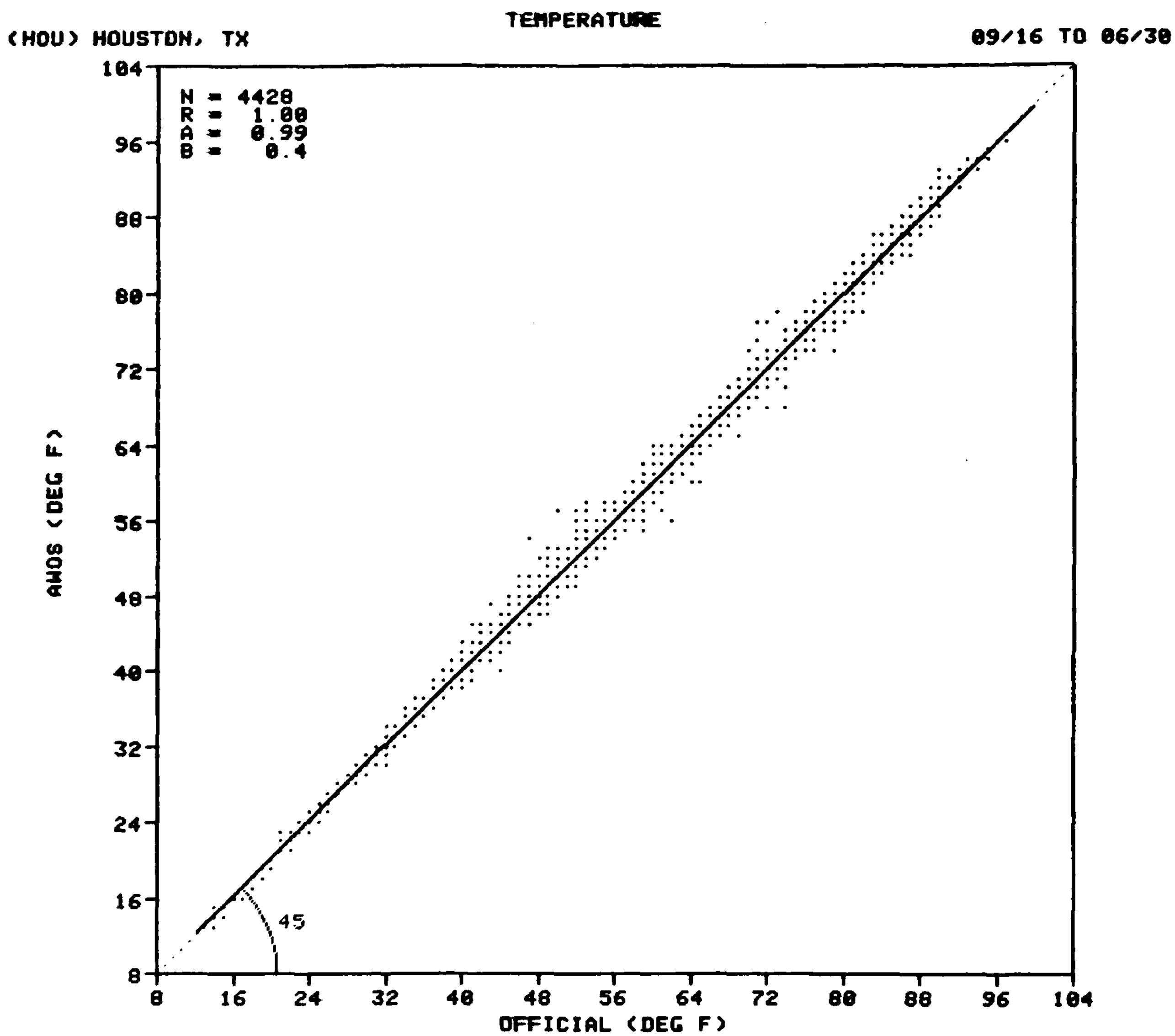
(HOU) HOUSTON, TX
VISIBILITY
(OFFICIAL < 2 MI)
09/16 TO 06/30
N = 258
R = 0.69
A = 1.34
B = 0.4
45
AWOS (MI)
OFFICIAL (MI)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

84-20-D-14b

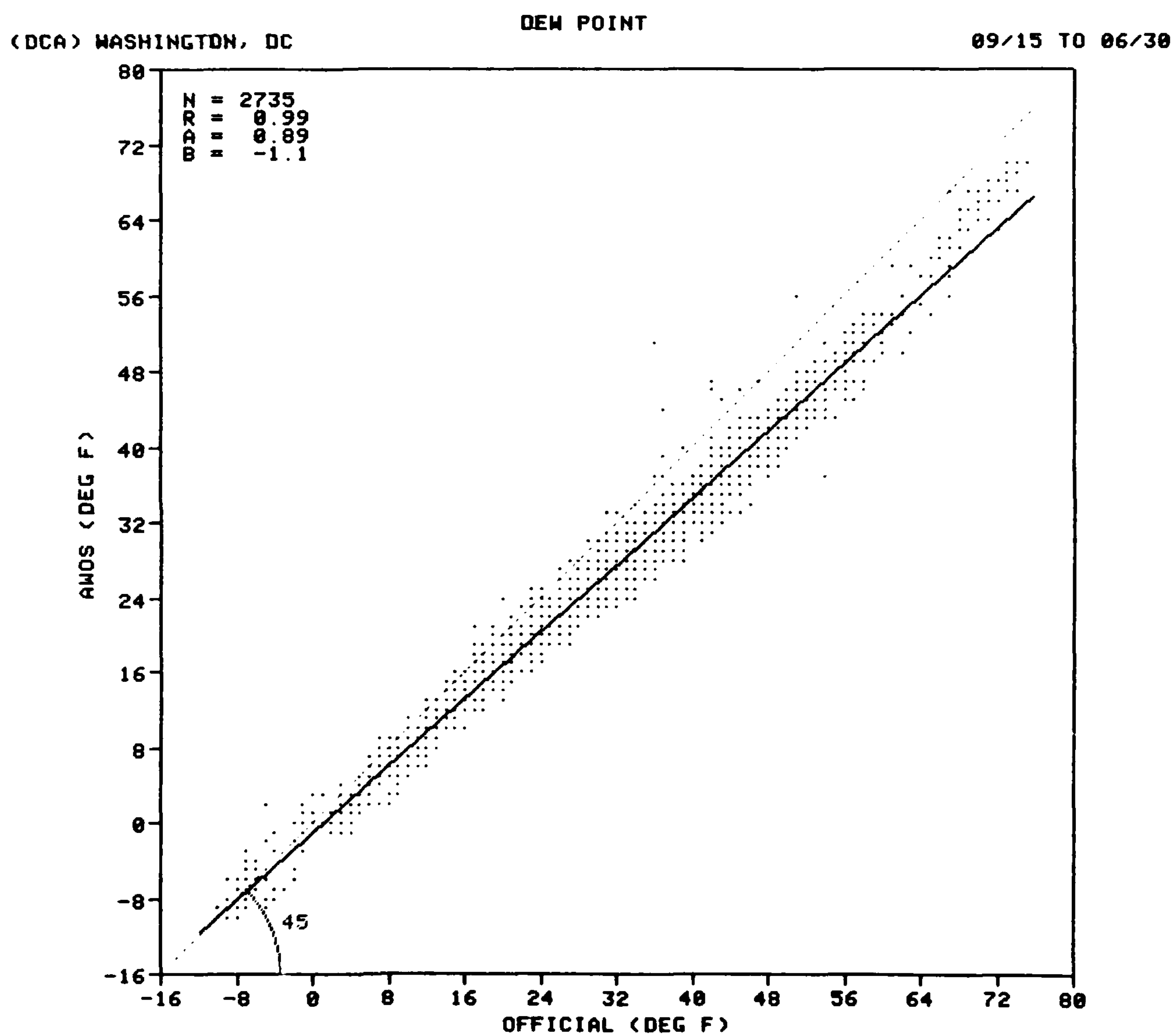


TEMPERATURE
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2968
R = 1.00
A = 1.00
B = -1.2
45
AWOS (DEG F)
OFFICIAL (DEG F)
0
10
20
30
40
50
60
70
80
90
100
110
120

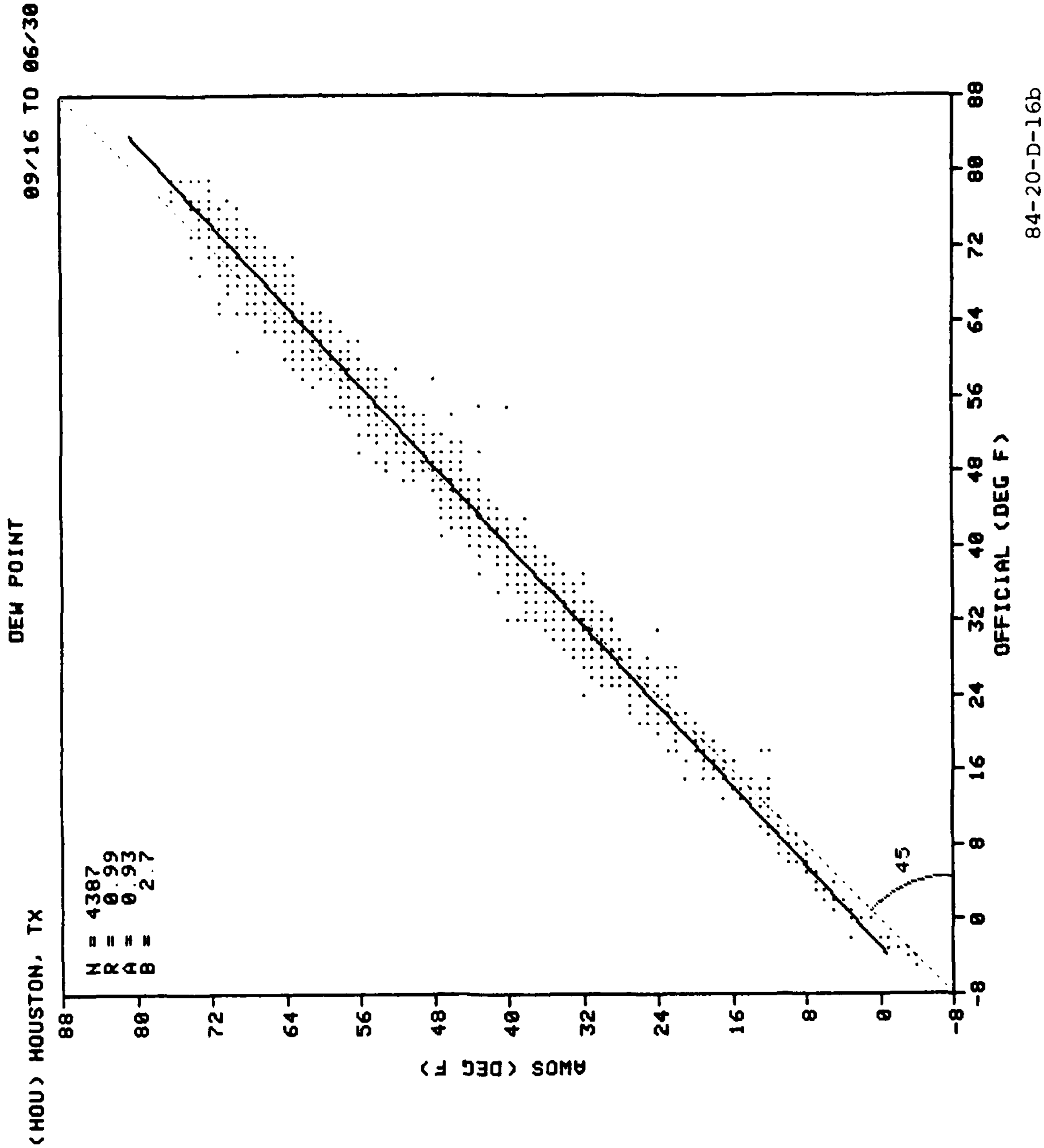
84-20-D-15a


TEMPERATURE
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4428
R = 1.00
A = 0.99
B = 0.4
45
AWOS (DEG F)
OFFICIAL (DEG F)
8
16
24
32
40
48
56
64
72
80
88
96
104

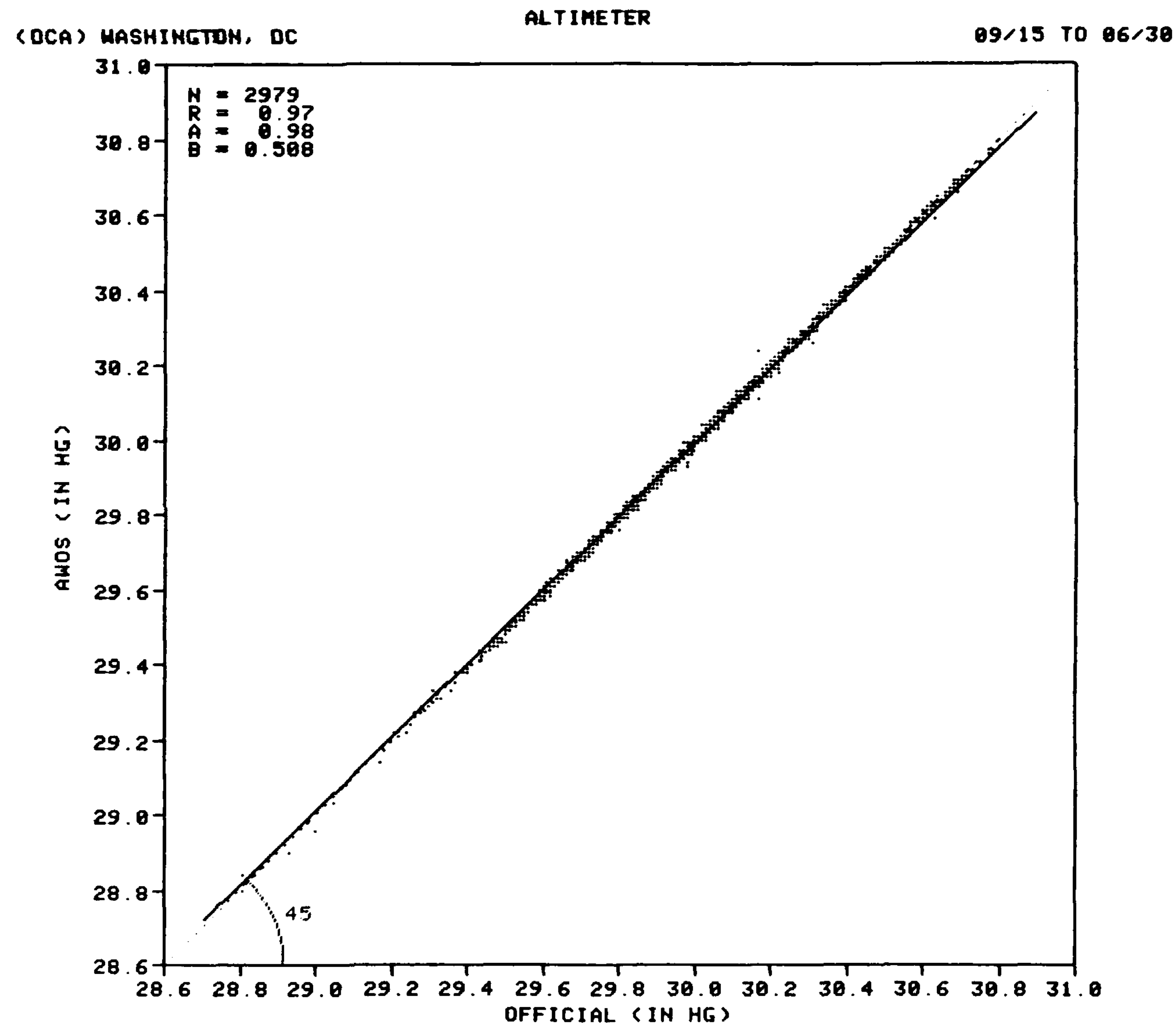
84-20-D-15b


DEW POINT
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2735
R = 0.99
A = 0.89
B = -1.1
AWOS (DEG F)
OFFICIAL (DEG F)
45
-16
-8
0
8
16
24
32
40
48
56
64
72
80

84-20-D-16a

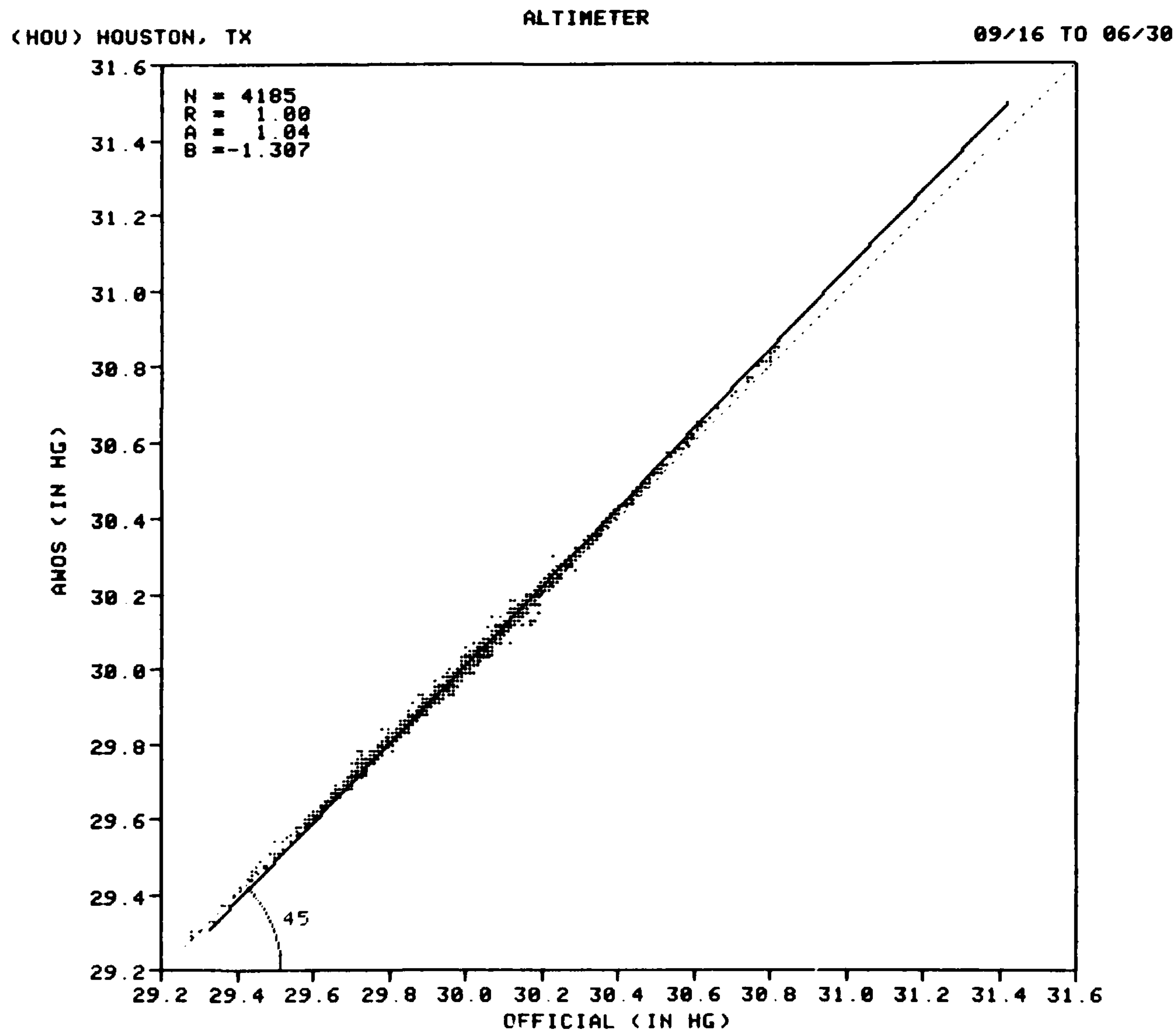


(HOU) HOUSTON, TX
DEW POINT
09/16 TO 06/30
N = 4387
R = 0.99
A = 0.93
B = 2.7
45
AWOS (DEG F)
OFFICIAL (DEG F)
-8
0
8
16
24
32
40
48
56
64
72
80
88
84-20-D-16b



ALTIMETER
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2979
R = 0.97
A = 0.98
B = 0.508
AWOS (IN HG)
OFFICIAL (IN HG)
45
28.6
28.8
29.0
29.2
29.4
29.6
29.8
30.0
30.2
30.4
30.6
30.8
31.0

84-20-D-17a

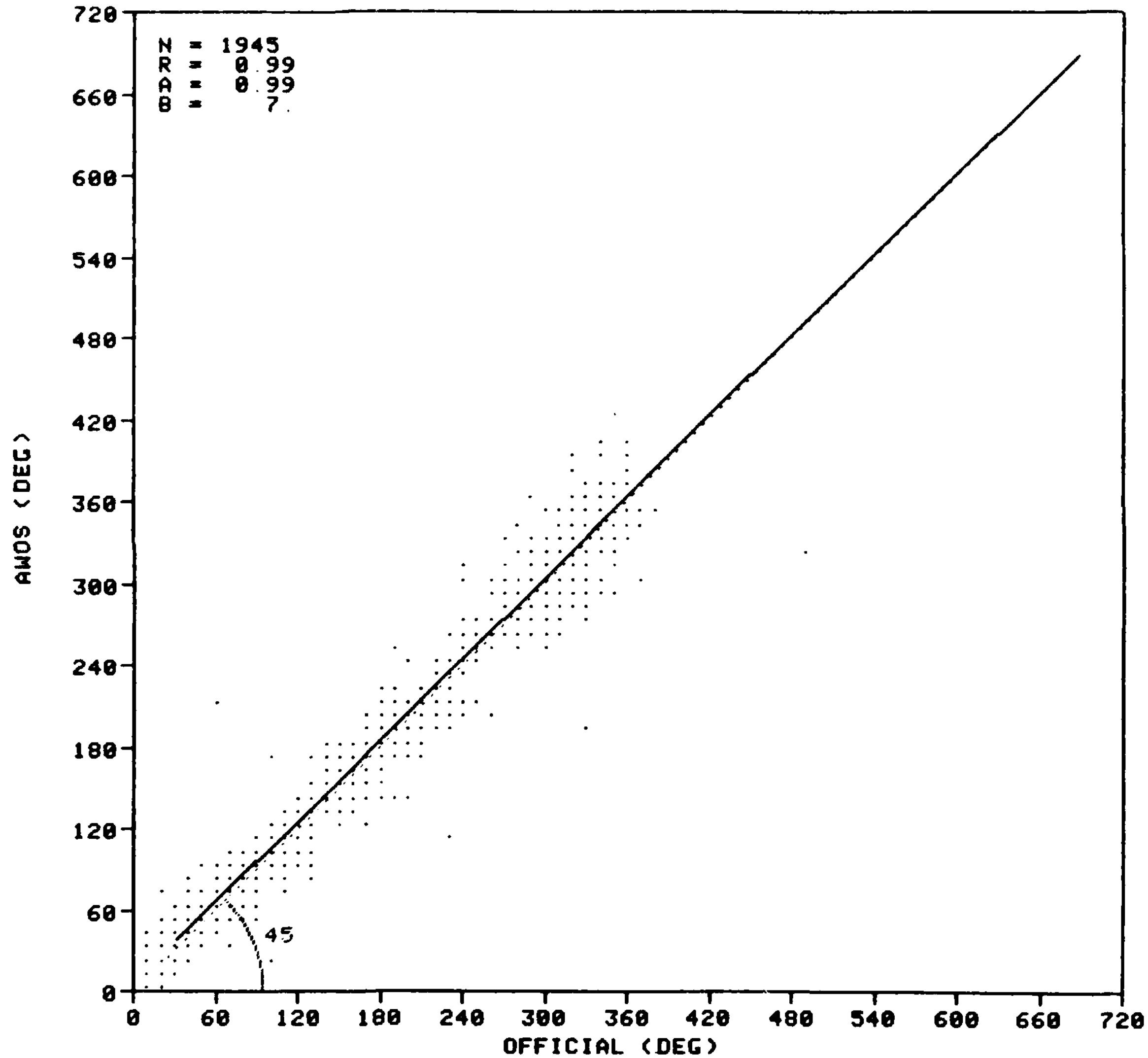

(HOU) HOUSTON, TX
ALTIMETER
09/16 TO 06/30
N = 4185
R = 1.00
A = 1.04
B =-1.307
45
AWOS (IN HG)
OFFICIAL (IN HG)
29.2
29.4
29.6
29.8
30.0
30.2
30.4
30.6
30.8
31.0
31.2
31.4
31.6

84-20-D-17b

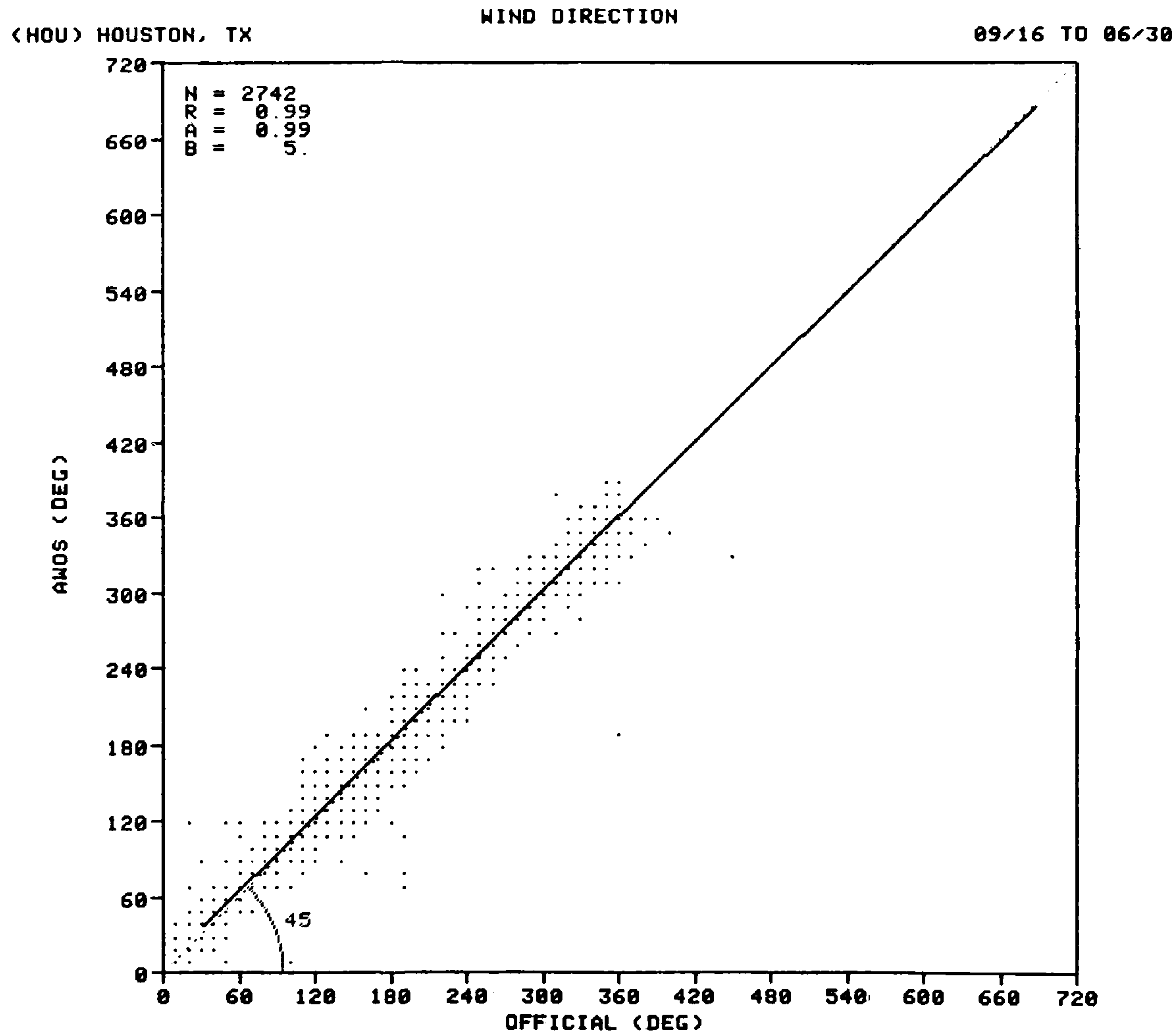
WIND DIRECTION

(DCA) WASHINGTON, DC

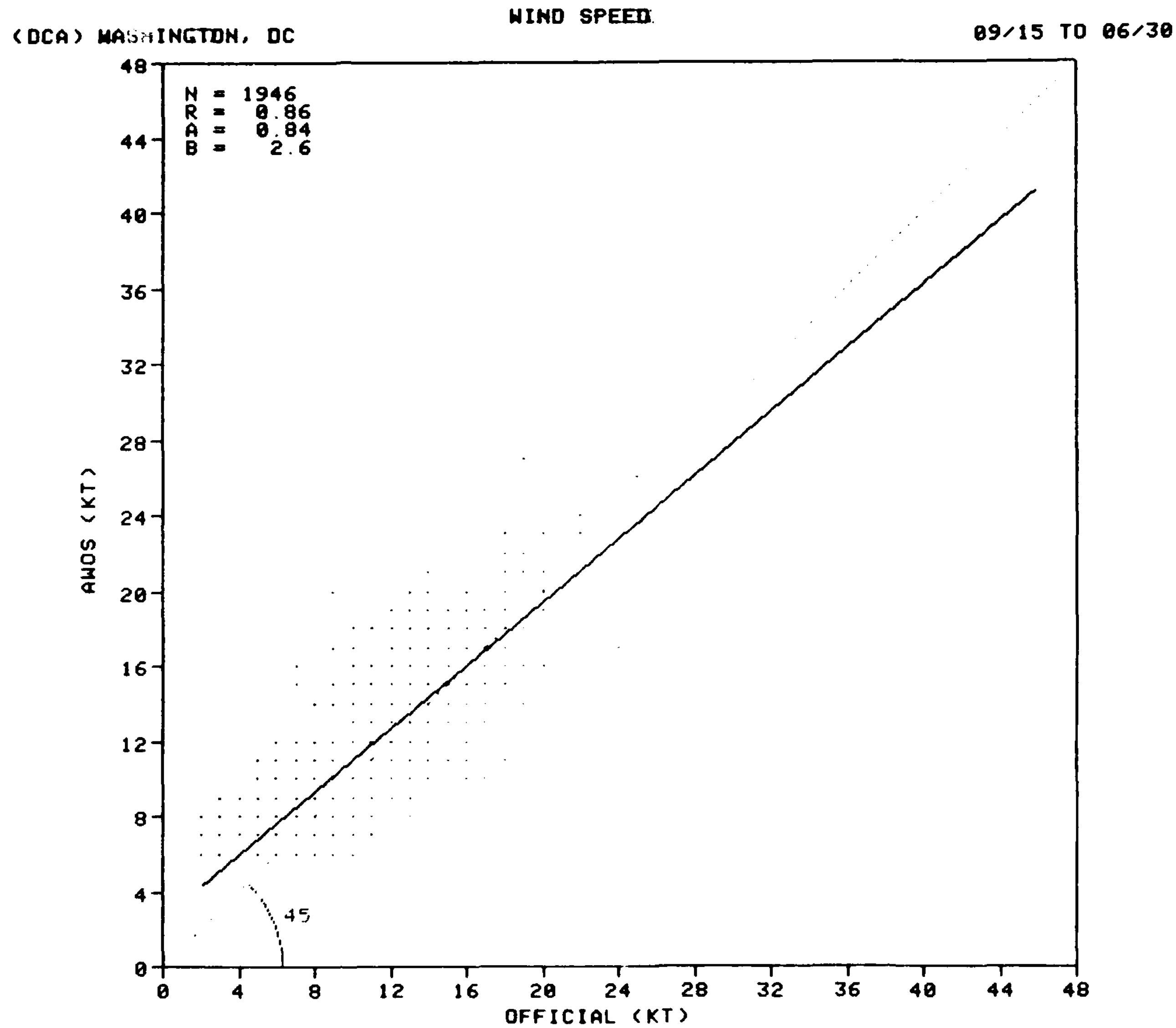
09/15 TO 06/30



84-20-D-18a


WIND DIRECTION
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 2742
R = 0.99
A = 0.99
B = 5.
45
AWOS (DEG)
OFFICIAL (DEG)
0
60
120
180
240
300
360
420
480
540
600
660
720

84-20-D-18b

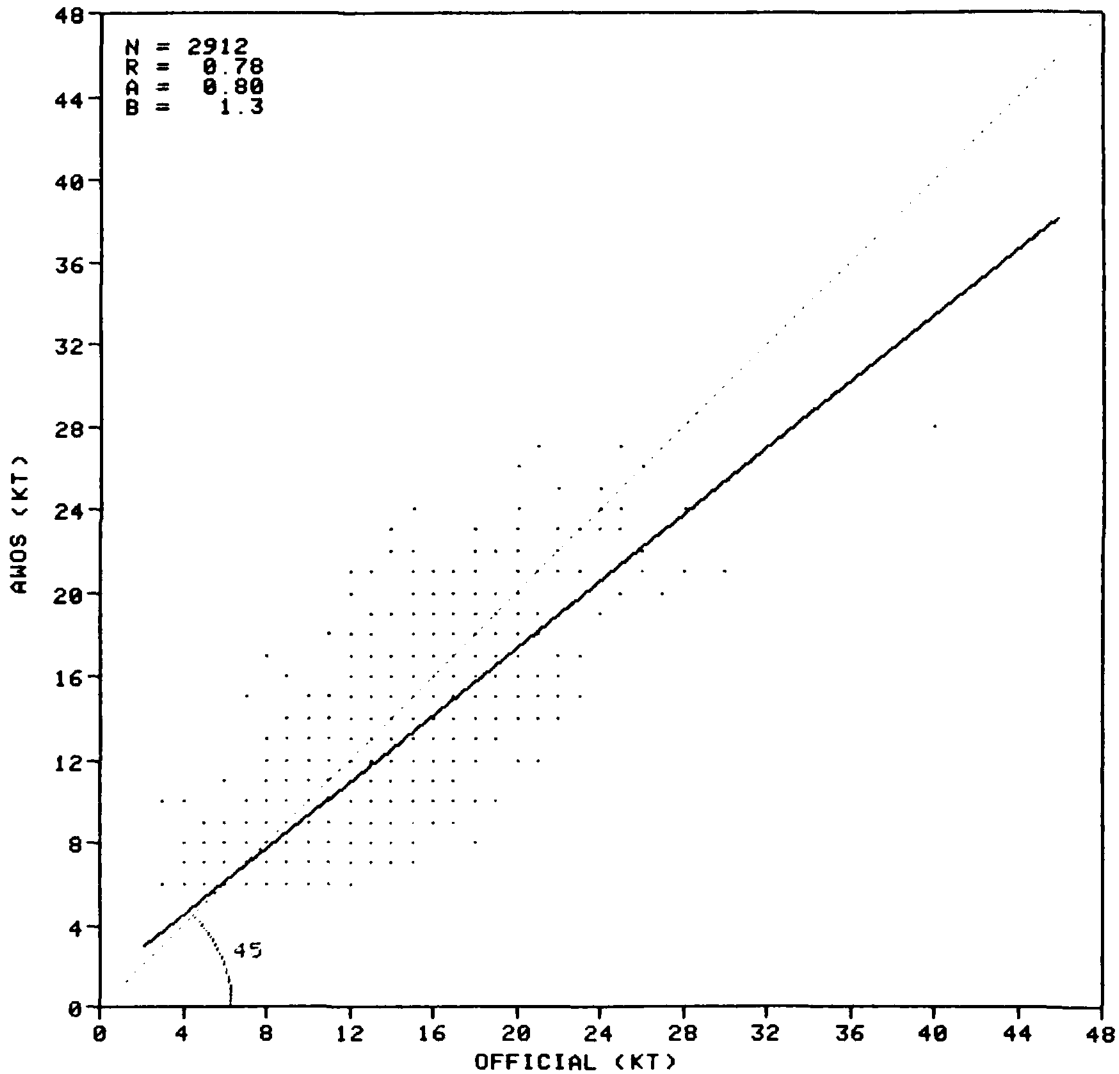

WIND SPEED
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 1946
R = 0.86
A = 0.84
B = 2.6
45
AWOS (KT)
OFFICIAL (KT)
0
4
8
12
16
20
24
28
32
36
40
44
48

84-20-D-19a

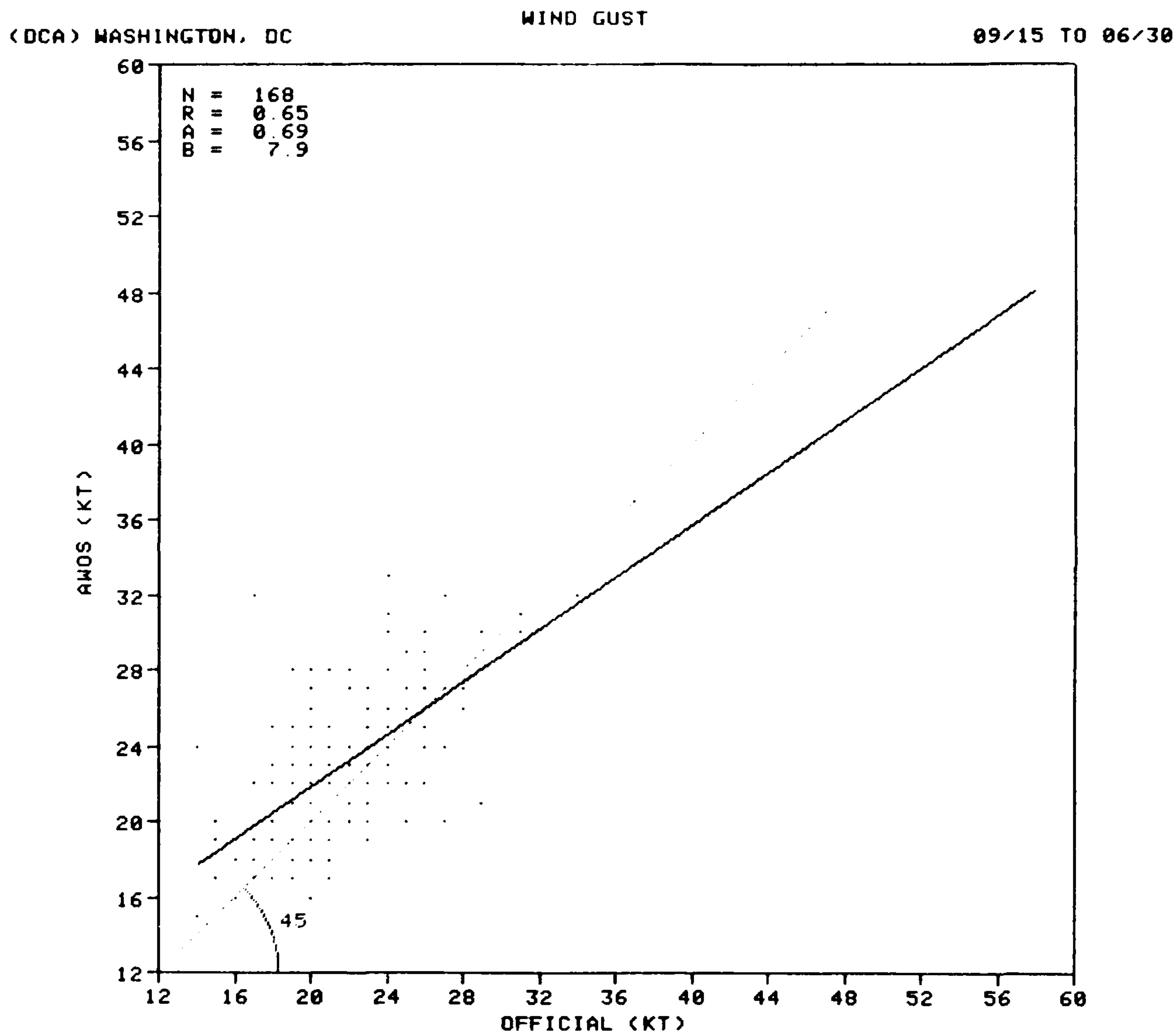
WIND SPEED

(HOU) HOUSTON, TX

09/16 TO 06/30



84-20-D-19b

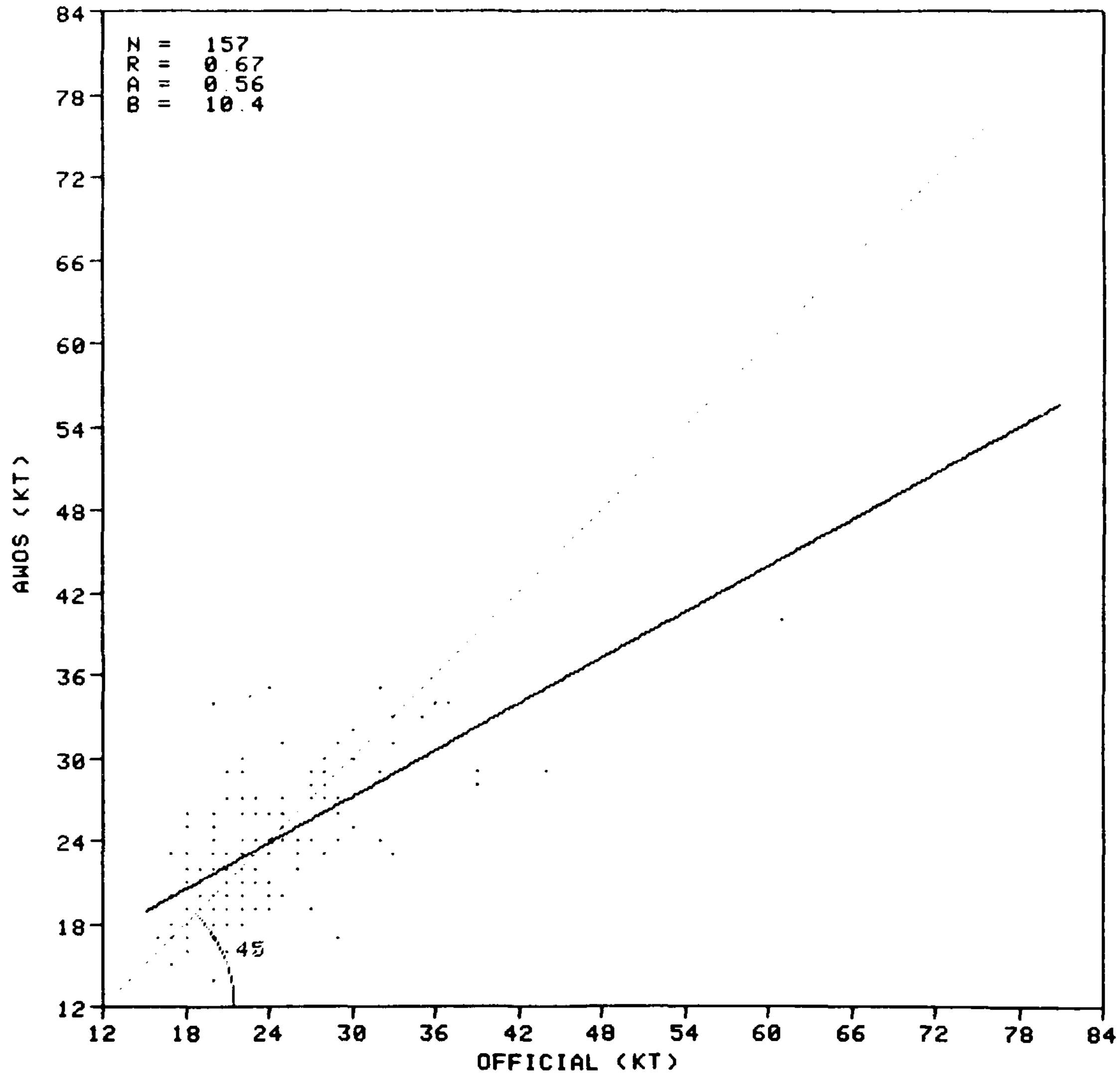

WIND GUST
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 168
R = 0.65
A = 0.69
B = 7.9
45
AWOS (KT)
OFFICIAL (KT)
12
16
20
24
28
32
36
40
44
48
52
56
60

84-20-D-20a

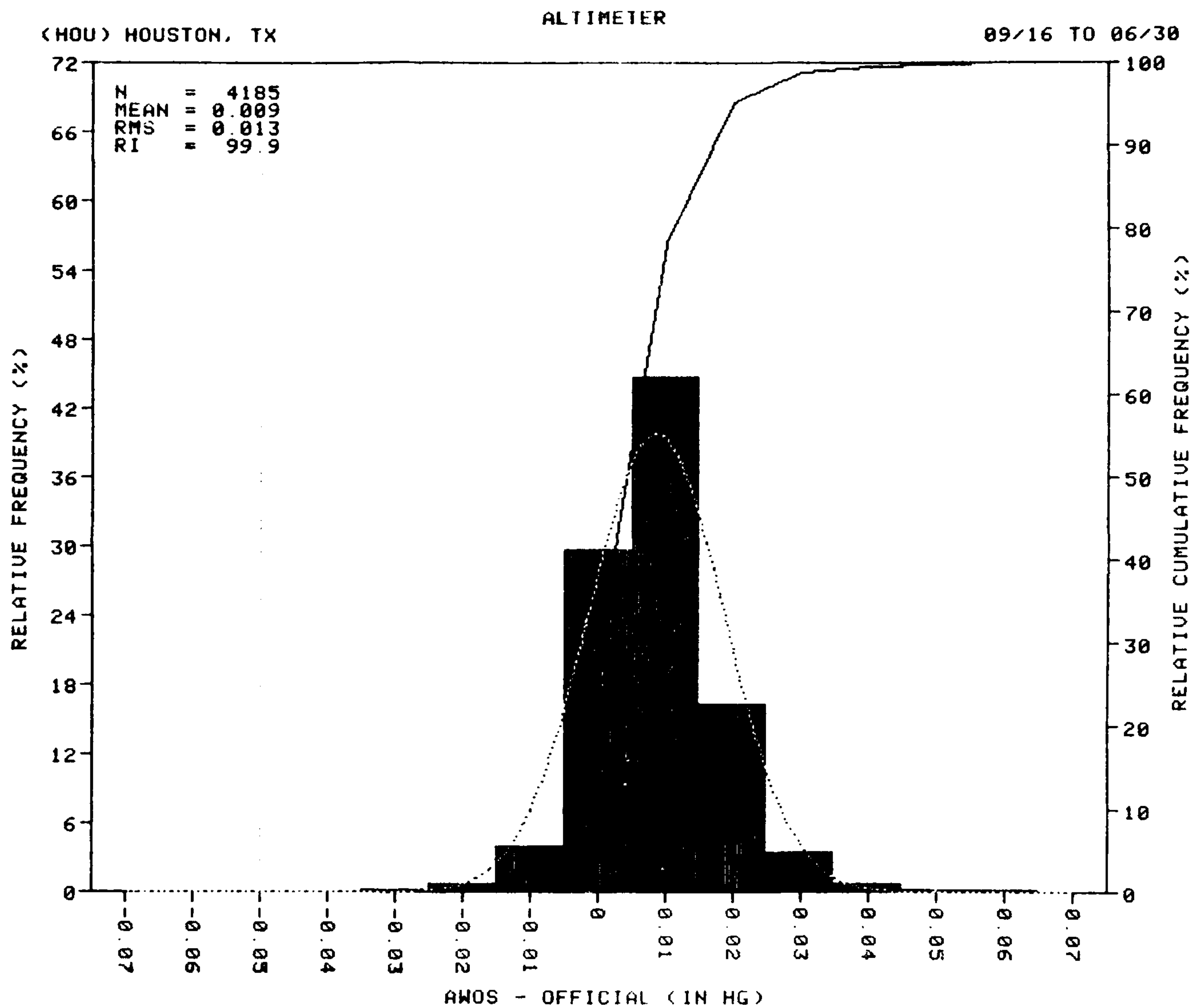
(HOU) HOUSTON, TX

WIND GUST

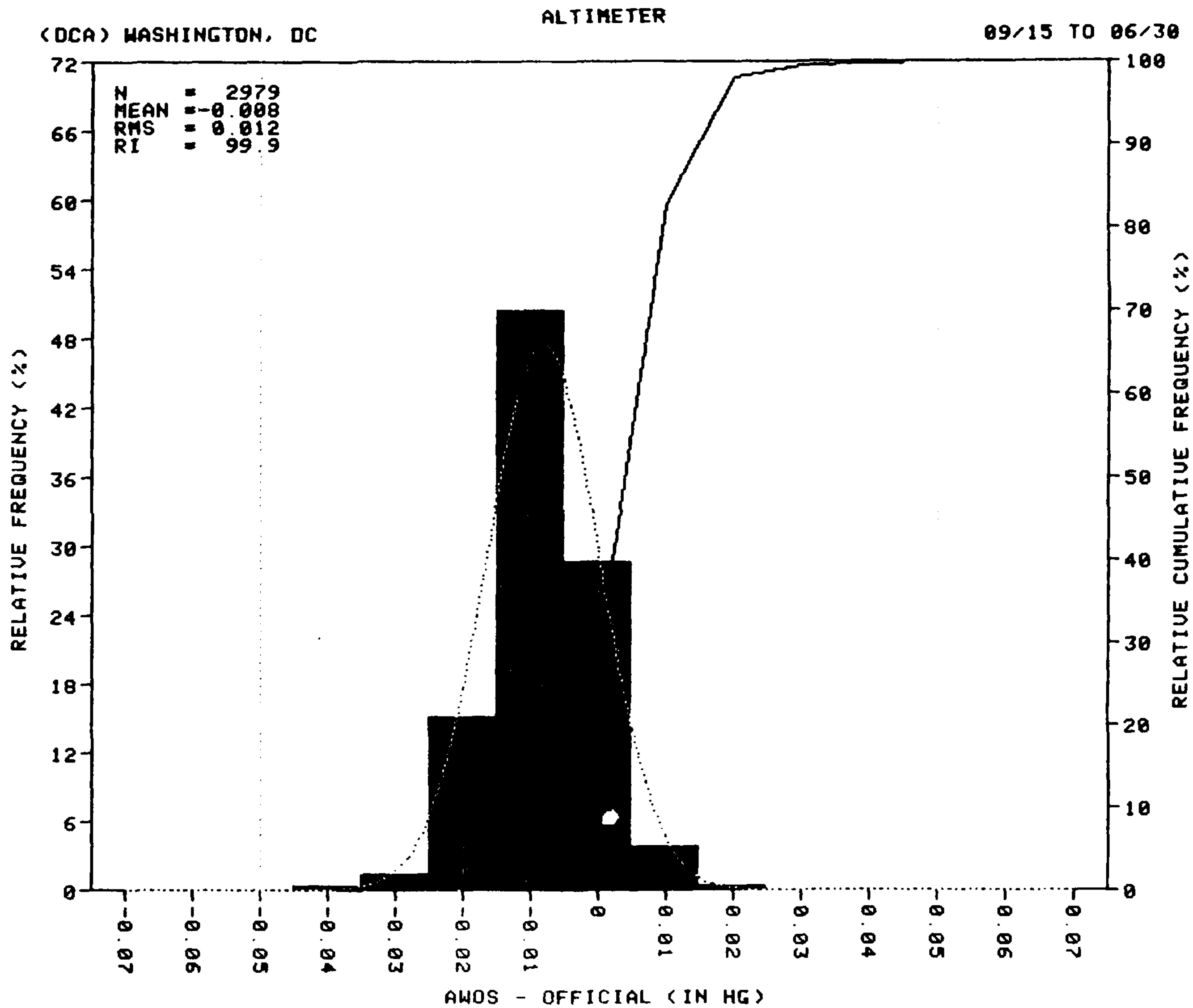
09/16 TO 06/30



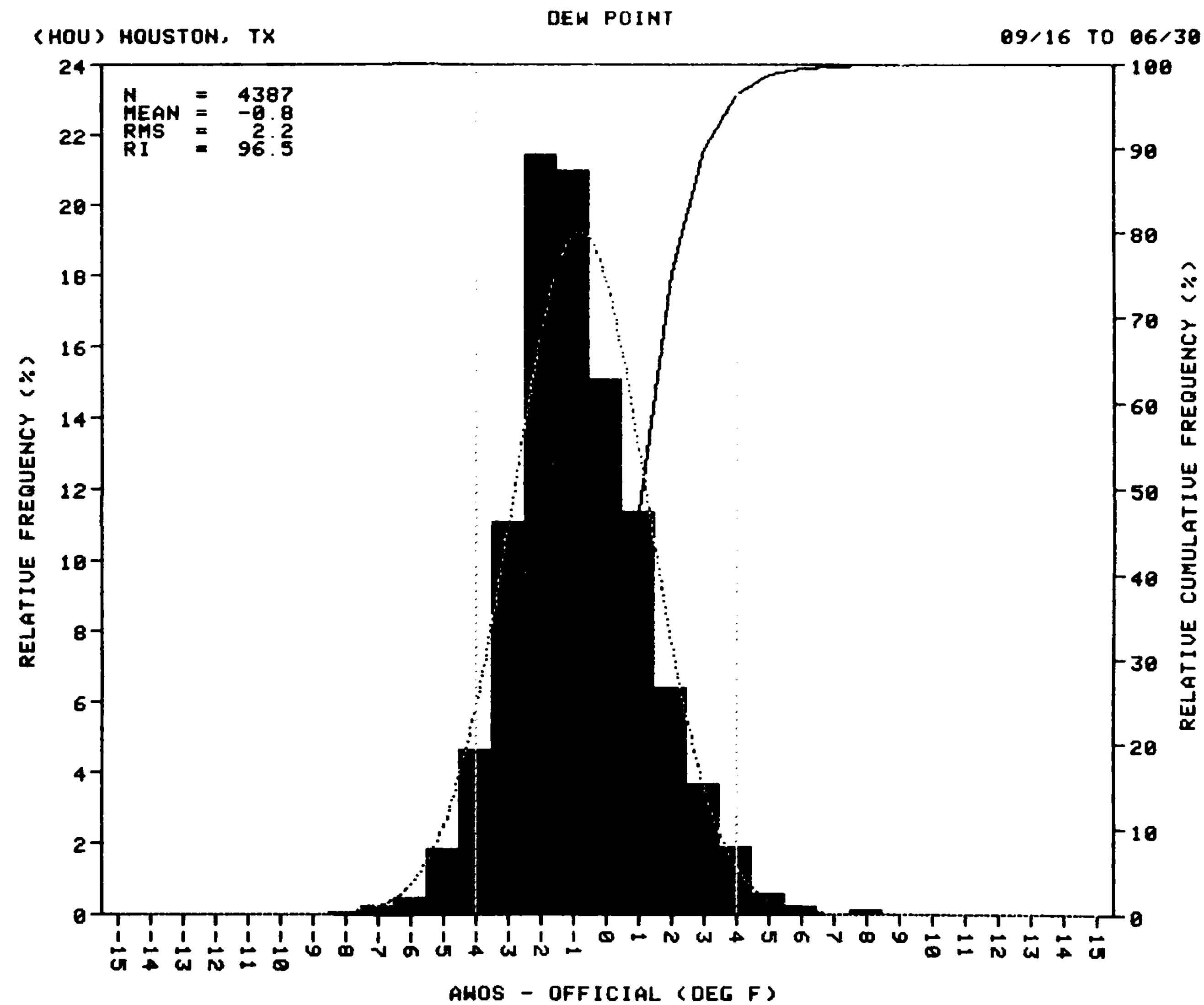
84-20-D-20b


ALTIMETER
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4185
MEAN = 0.009
RMS = 0.013
RI = 99.9
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (IN HG)
72
66
60
54
48
42
36
30
24
18
12
6
0
100
90
80
70
60
50
40
30
20
10
0
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07

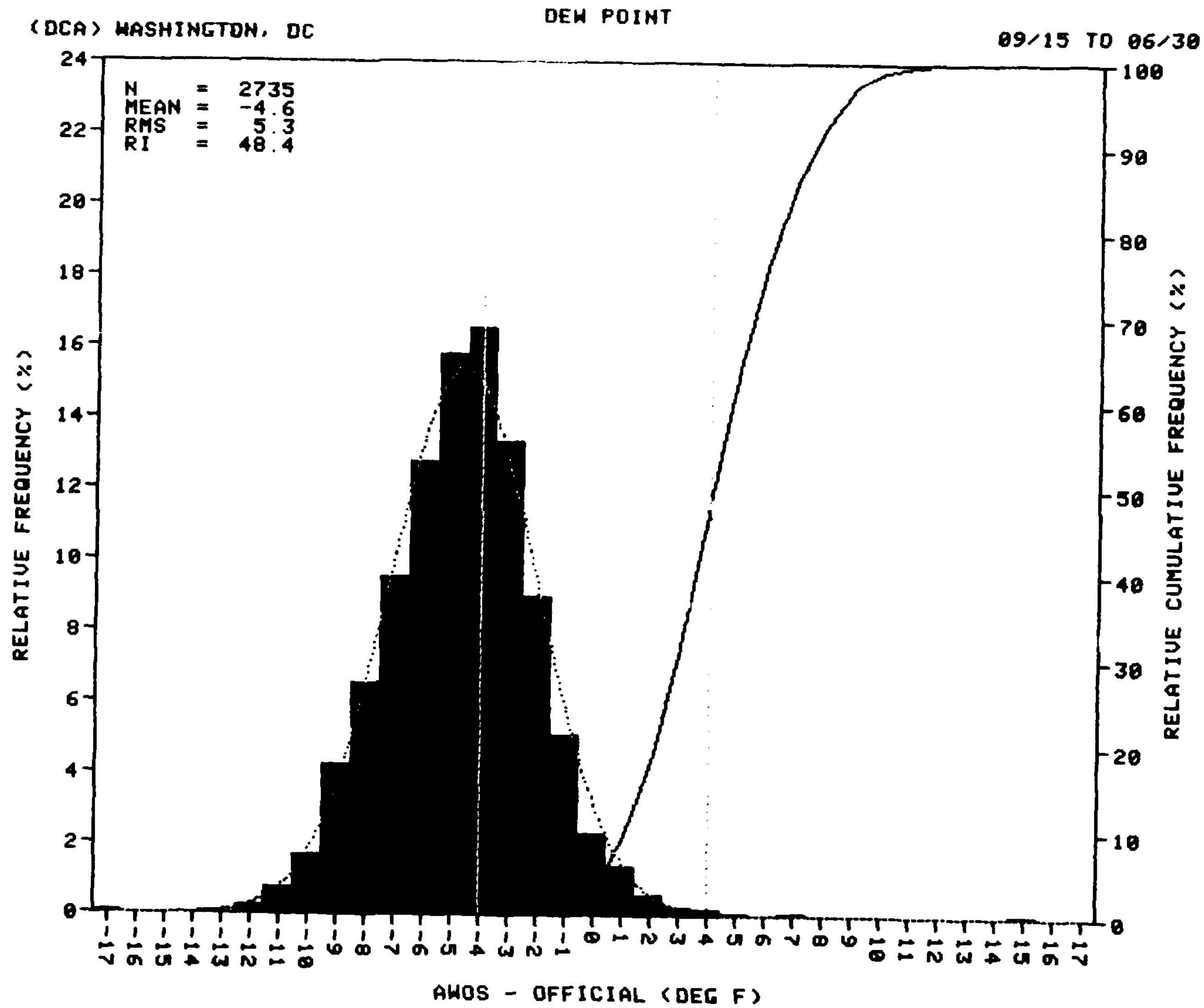
84-20-D-27b


ALTIMETER
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2979
MEAN =-0.008
RMS = 0.012
RI = 99.9
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (IN HG)

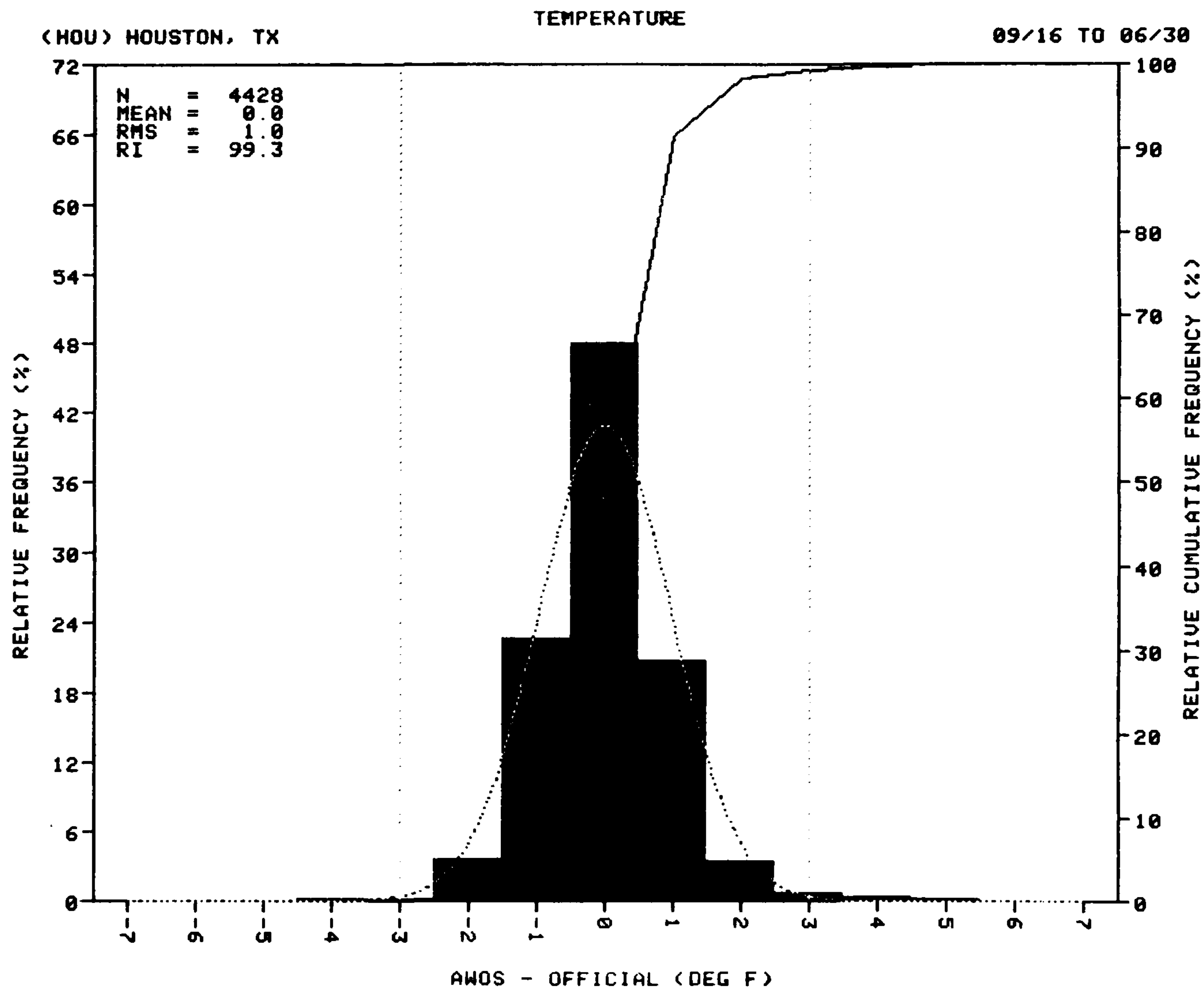
84-20-D-27a


DEW POINT
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4387
MEAN = -0.8
RMS = 2.2
RI = 96.5
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (DEG F)
0
2
4
6
8
10
12
14
16
18
20
22
24
10
20
30
40
50
60
70
80
90
100
-15
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
1
3
5
7
9
11
13
15

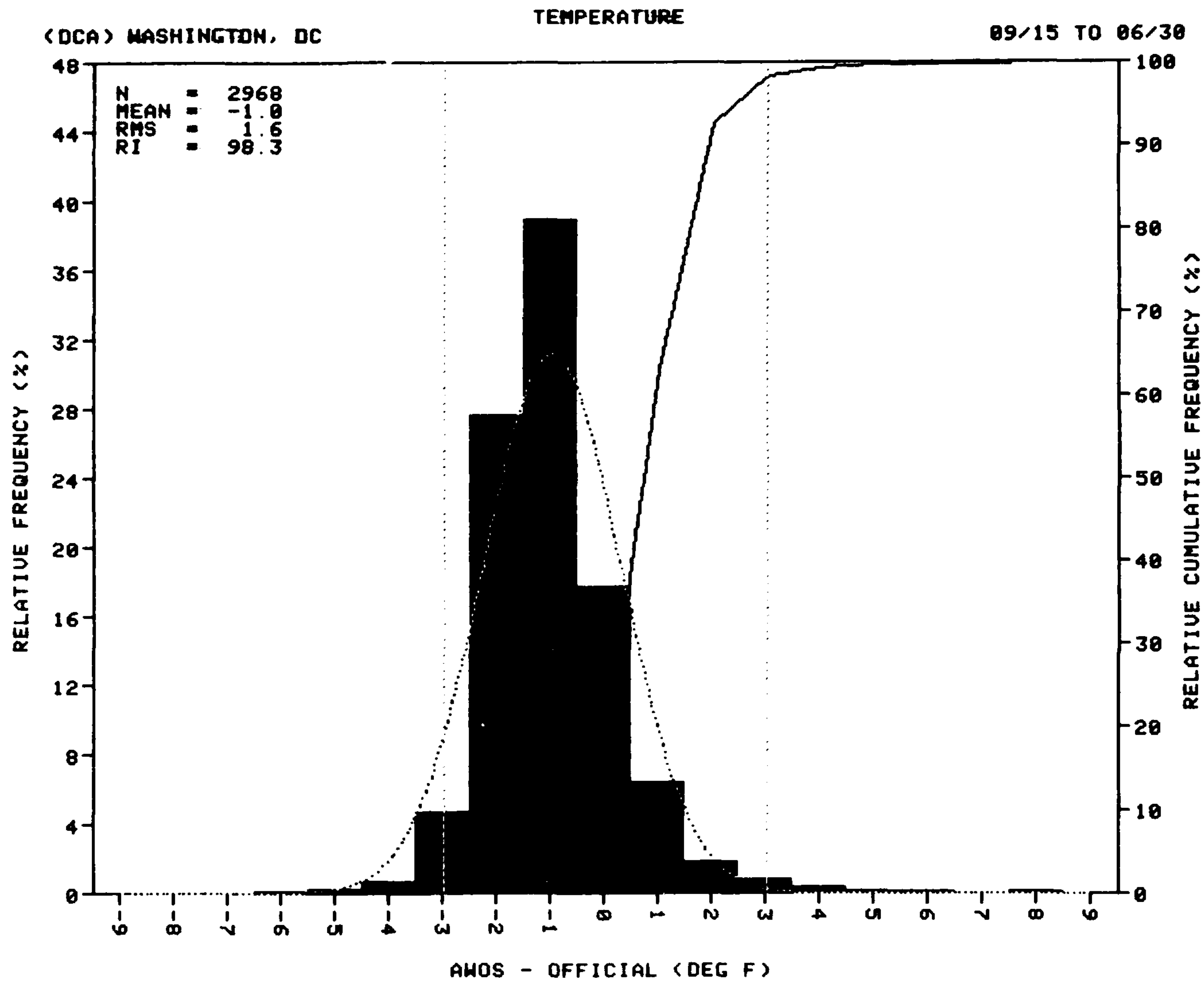
84-20-D-26b


(DCA) WASHINGTON, DC
DEW POINT
09/15 TO 06/30
N = 2735
MEAN = -4.6
RMS = 5.3
RI = 48.4
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (DEG F)

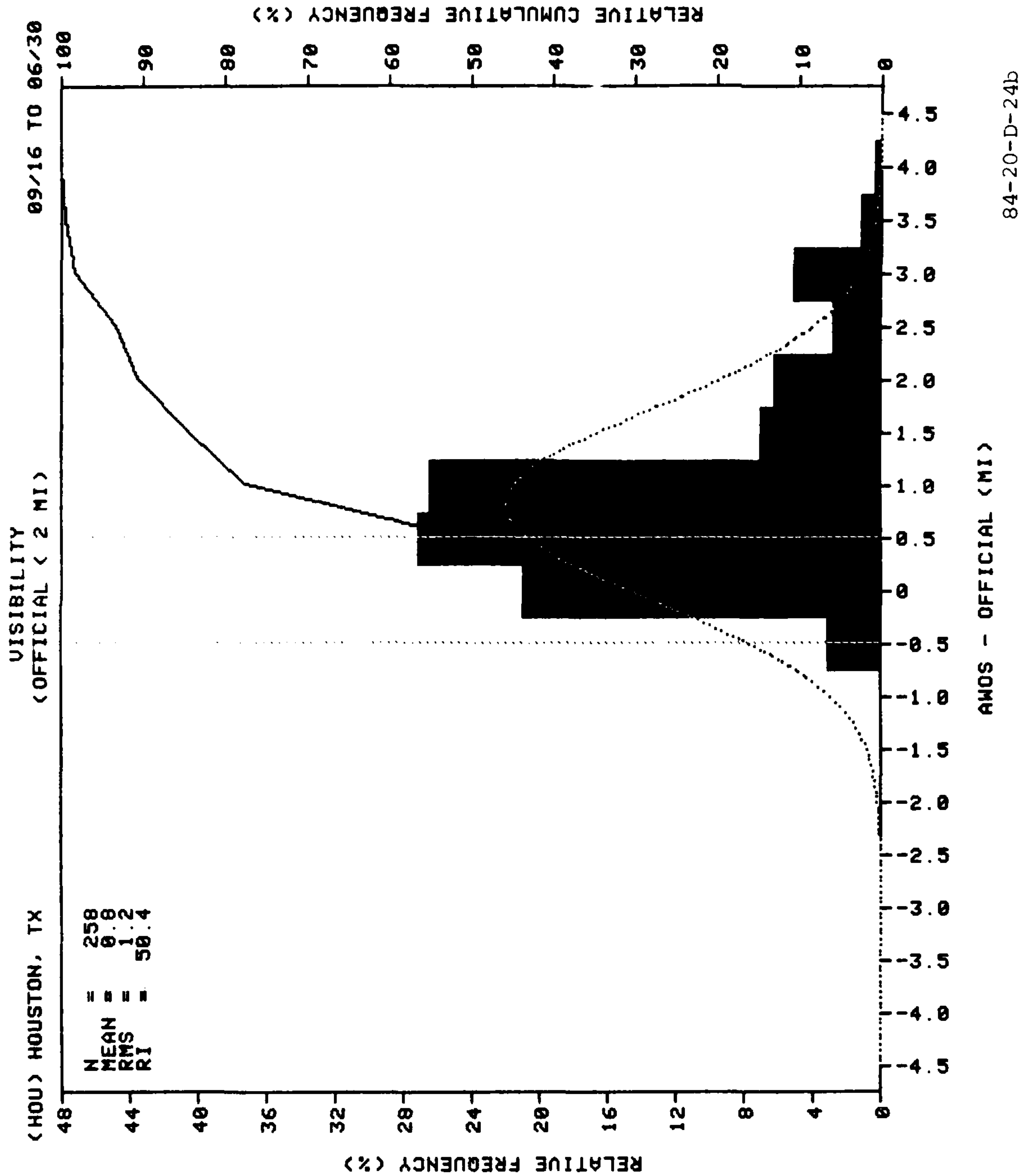
84-20-D-26a

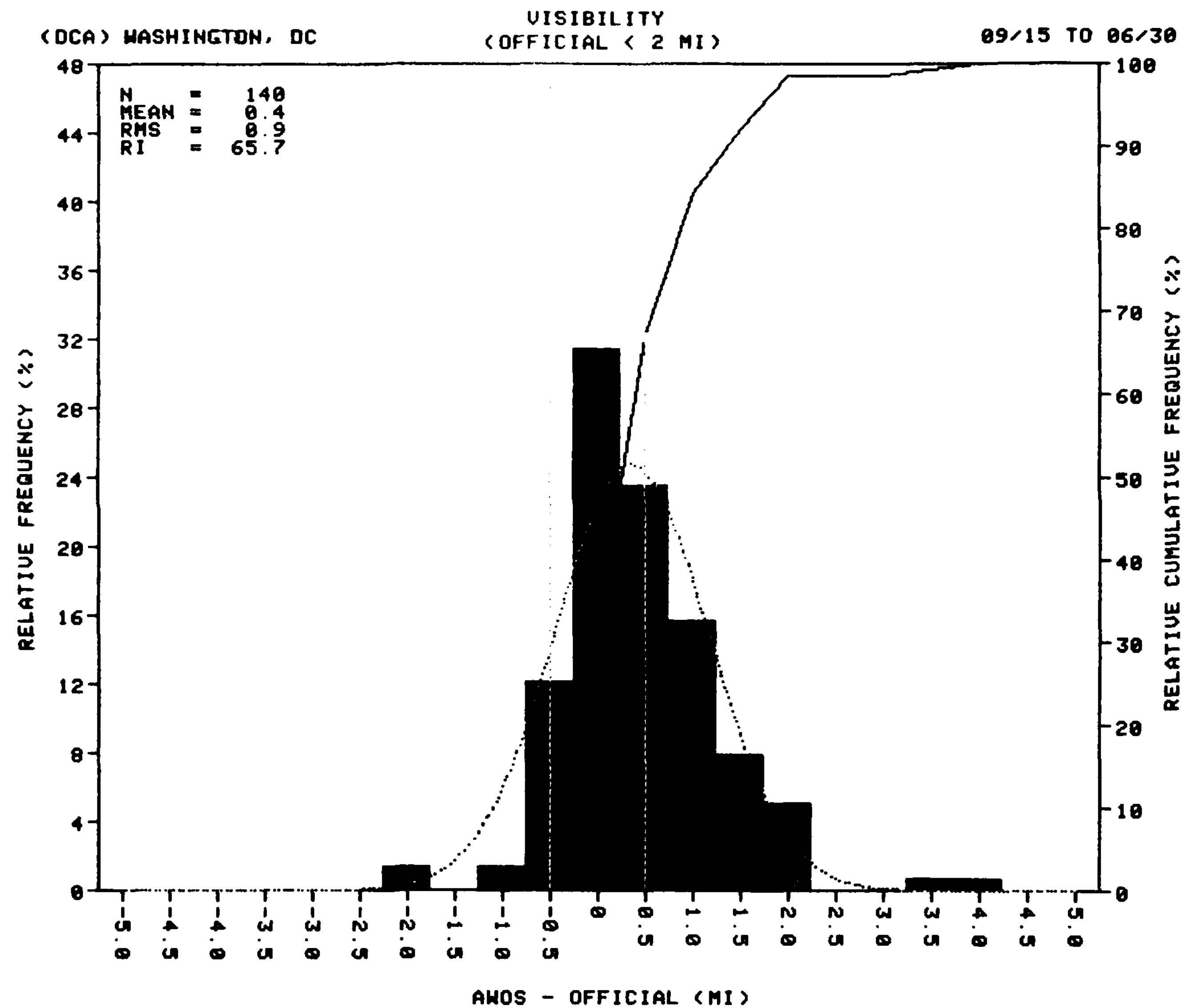

TEMPERATURE
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 4428
MEAN = 0.0
RMS = 1.0
RI = 99.3
RELATIVE FREQUENCY (%)
72
66
60
54
48
42
36
30
24
18
12
6
0
RELATIVE CUMULATIVE FREQUENCY (%)
100
90
80
70
60
50
40
30
20
10
0
-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
AWOS - OFFICIAL (DEG F)

84-20-D-25b

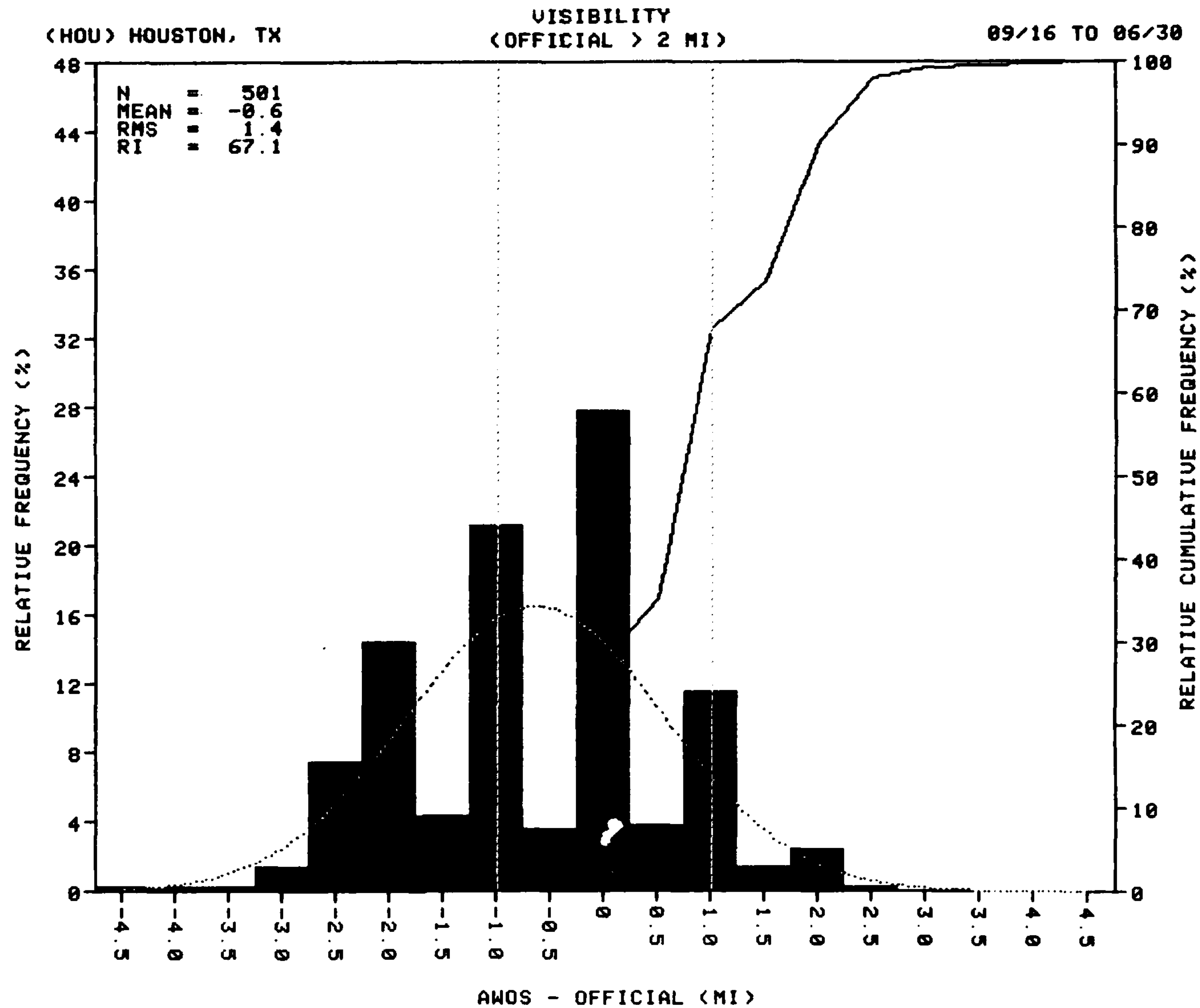

TEMPERATURE
(DCA) WASHINGTON, DC
09/15 TO 06/30
N = 2968
MEAN = -1.0
RMS = 1.6
RI = 98.3
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (DEG F)

84-20-D-25a


(HOU) HOUSTON, TX
VISIBILITY
(OFFICIAL < 2 MI)
09/16 TO 06/30
N = 258
MEAN = 0.8
RMS = 1.2
RI = 50.4
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (MI)
84-20-D-24b

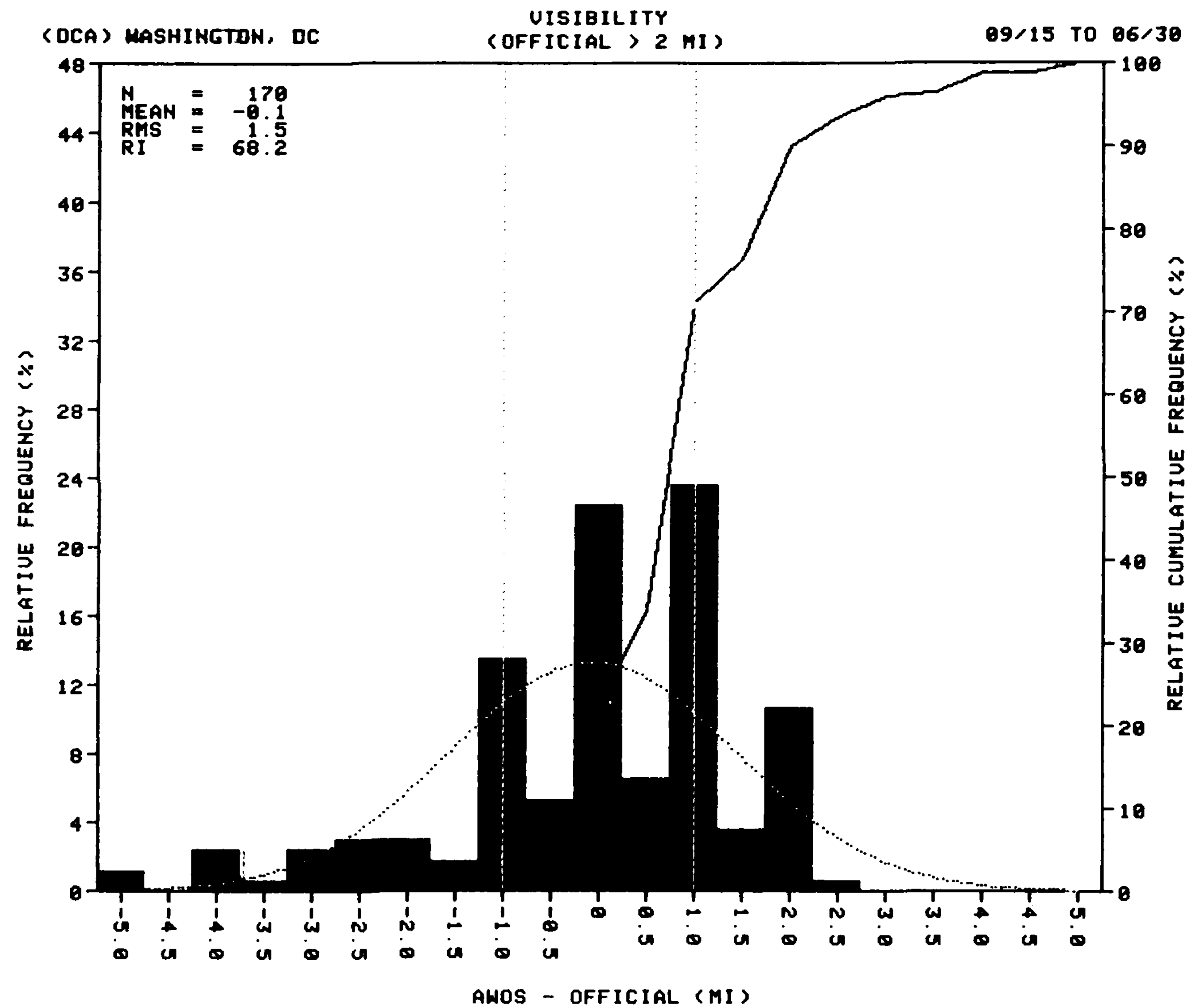

(DCA) WASHINGTON, DC
VISIBILITY
(OFFICIAL < 2 MI)
09/15 TO 06/30
N = 140
MEAN = 0.4
RMS = 0.9
RI = 65.7
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (MI)

84-20-D-24a



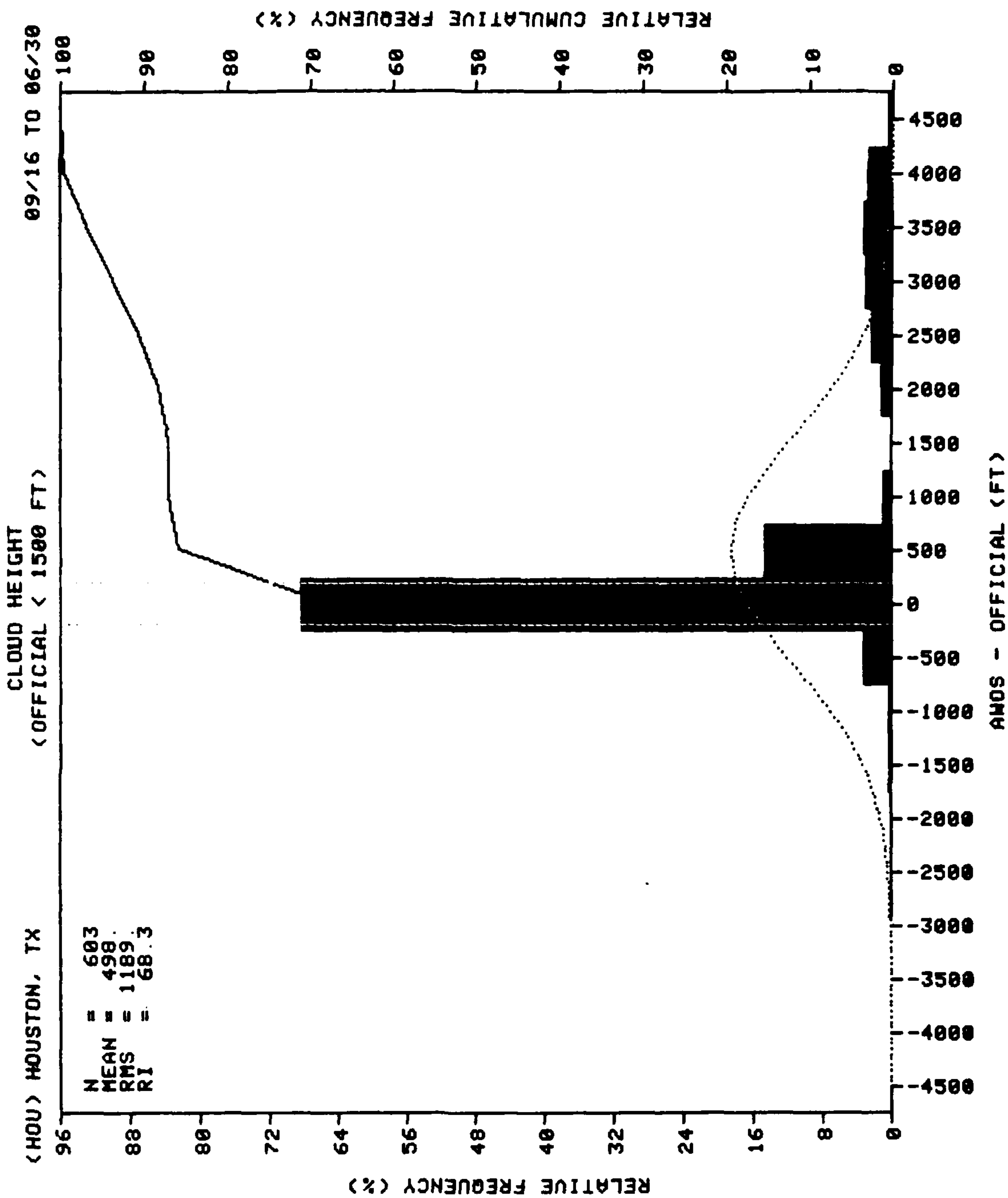
(HOU) HOUSTON, TX
VISIBILITY
(OFFICIAL > 2 MI)
09/16 TO 06/30
N = 501
MEAN = -0.6
RMS = 1.4
RI = 67.1
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (MI)

84-20-D-23b

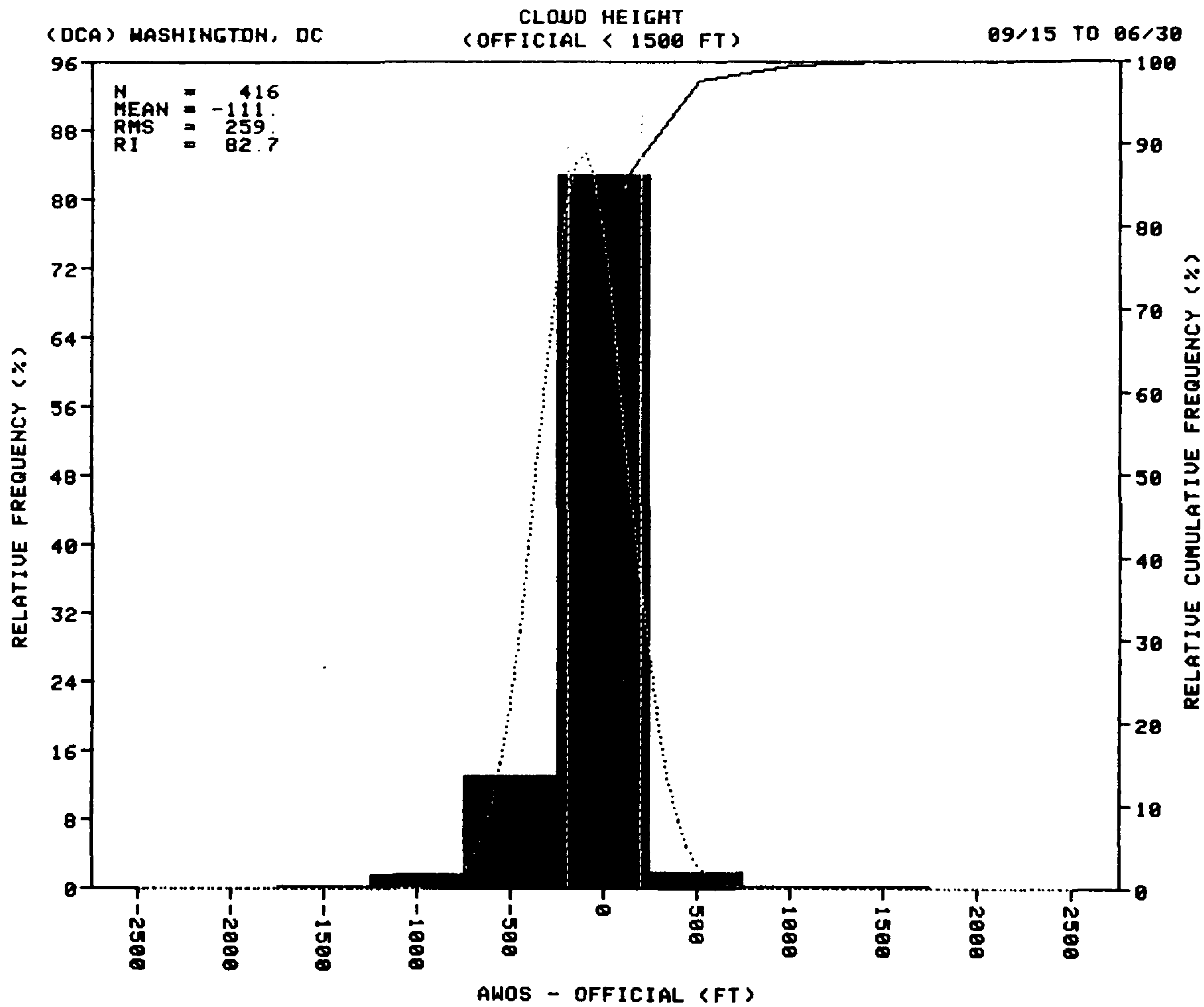


(DCA) WASHINGTON, DC
VISIBILITY
(OFFICIAL > 2 MI)
09/15 TO 06/30
N = 170
MEAN = -0.1
RMS = 1.5
RI = 68.2
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (MI)

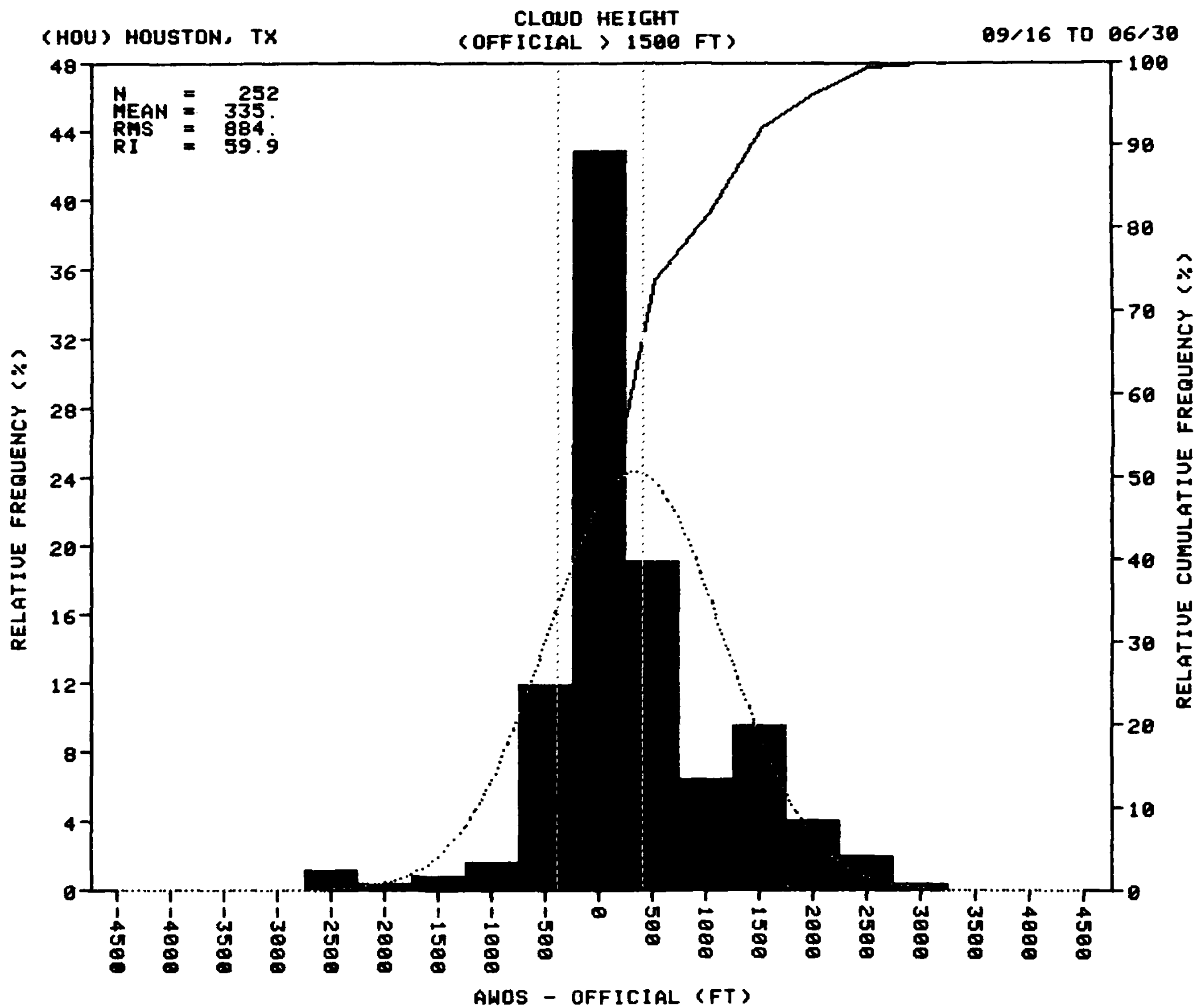
84-20-D-23a


CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/16 TO 06/30
(HOU) HOUSTON, TX
N = 603
MEAN = 498
RMS = 1189
RI = 68.3
RELATIVE CUMULATIVE FREQUENCY (%)
RELATIVE FREQUENCY (%)
AWOS - OFFICIAL (FT)
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
10
20
30
40
50
60
70
80
90
100
0
8
16
24
32
40
48
56
64
72
80
88
96

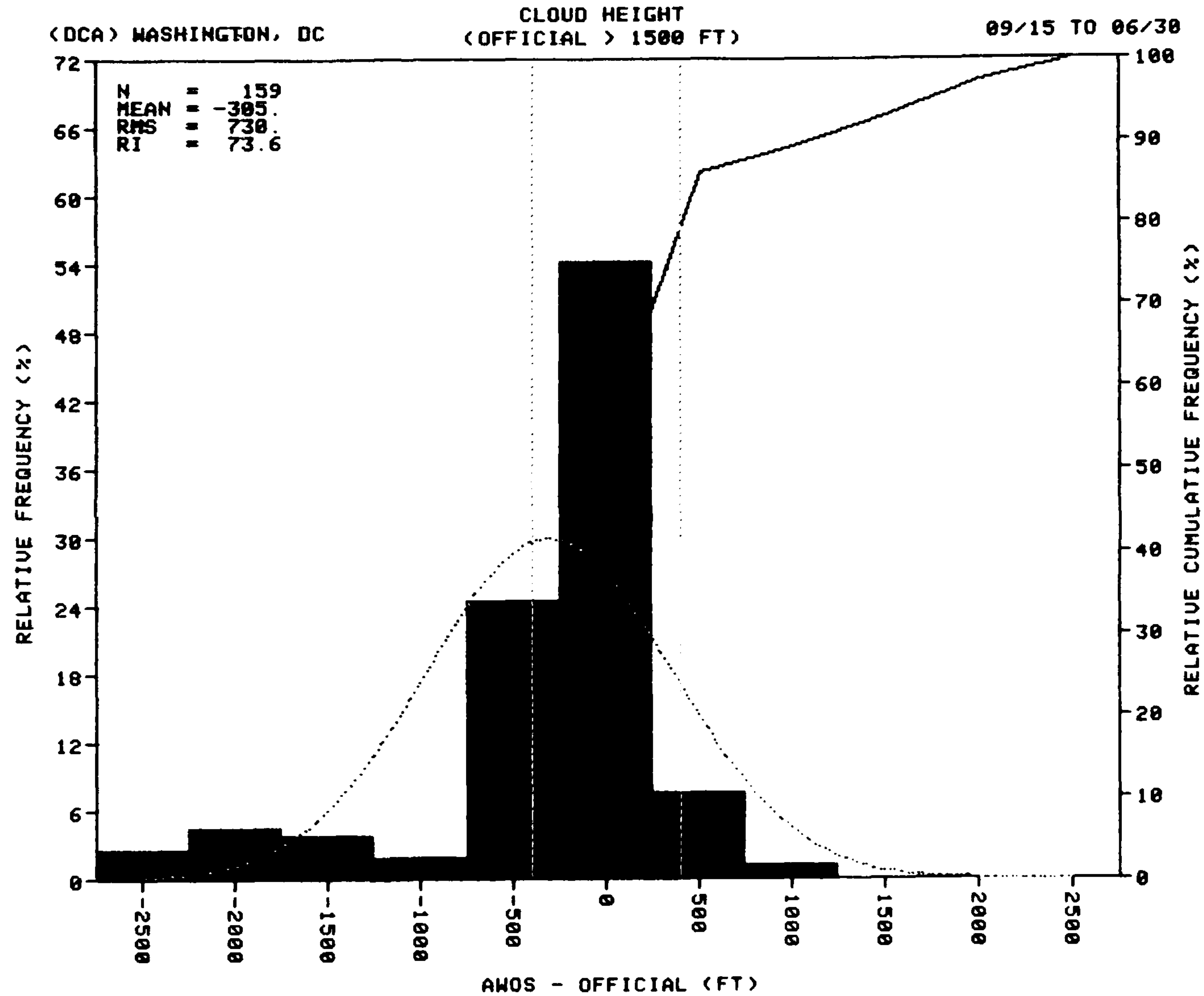
84-20-D-22b


(DCA) WASHINGTON, DC
CLOUD HEIGHT
(OFFICIAL < 1500 FT)
09/15 TO 06/30
N = 416
MEAN = -111.
RMS = 259.
RI = 82.7
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (FT)
96
88
80
72
64
56
48
40
32
24
16
8
0
100
90
80
70
60
50
40
30
20
10
0
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500

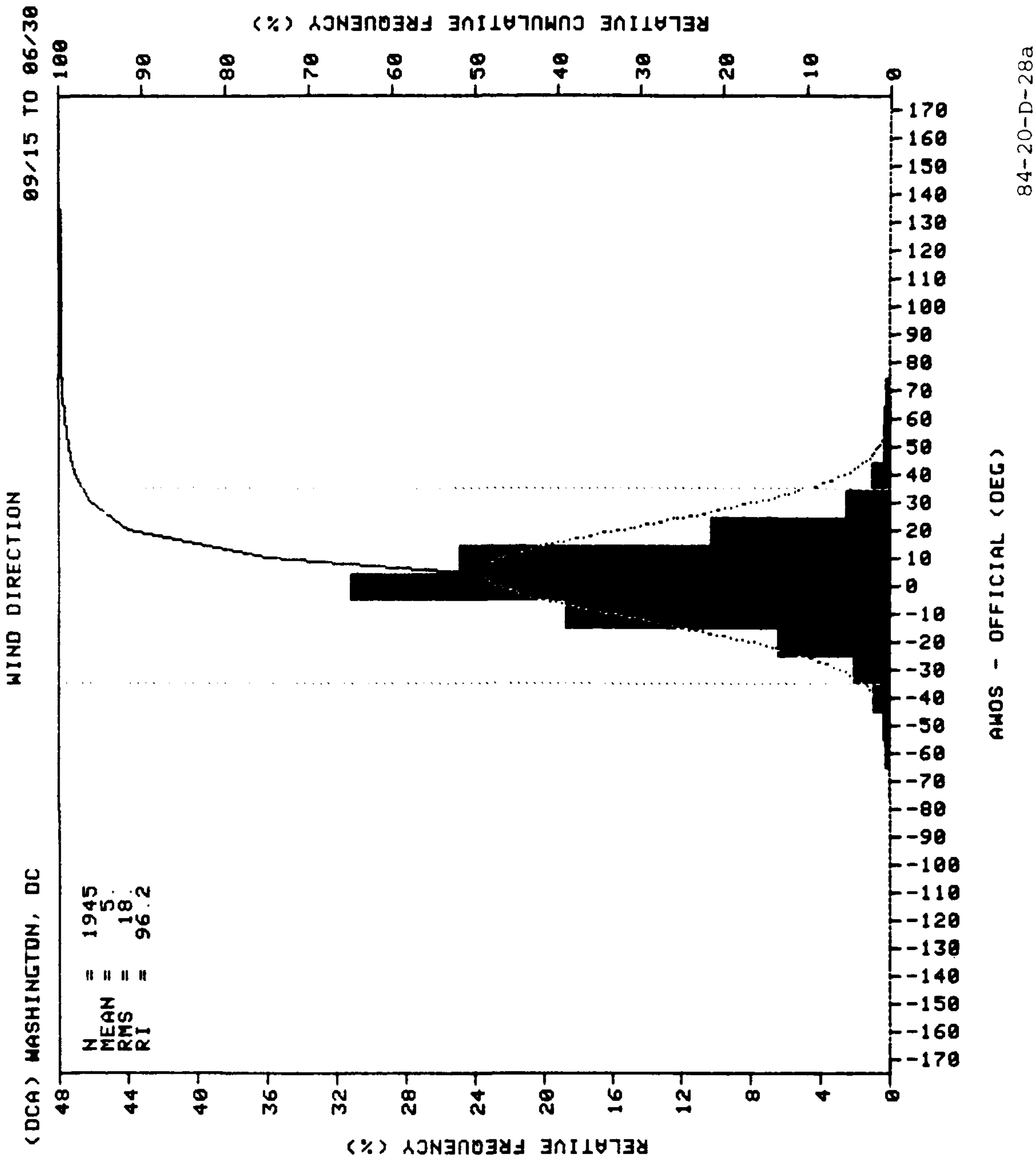
84-20-D-22a

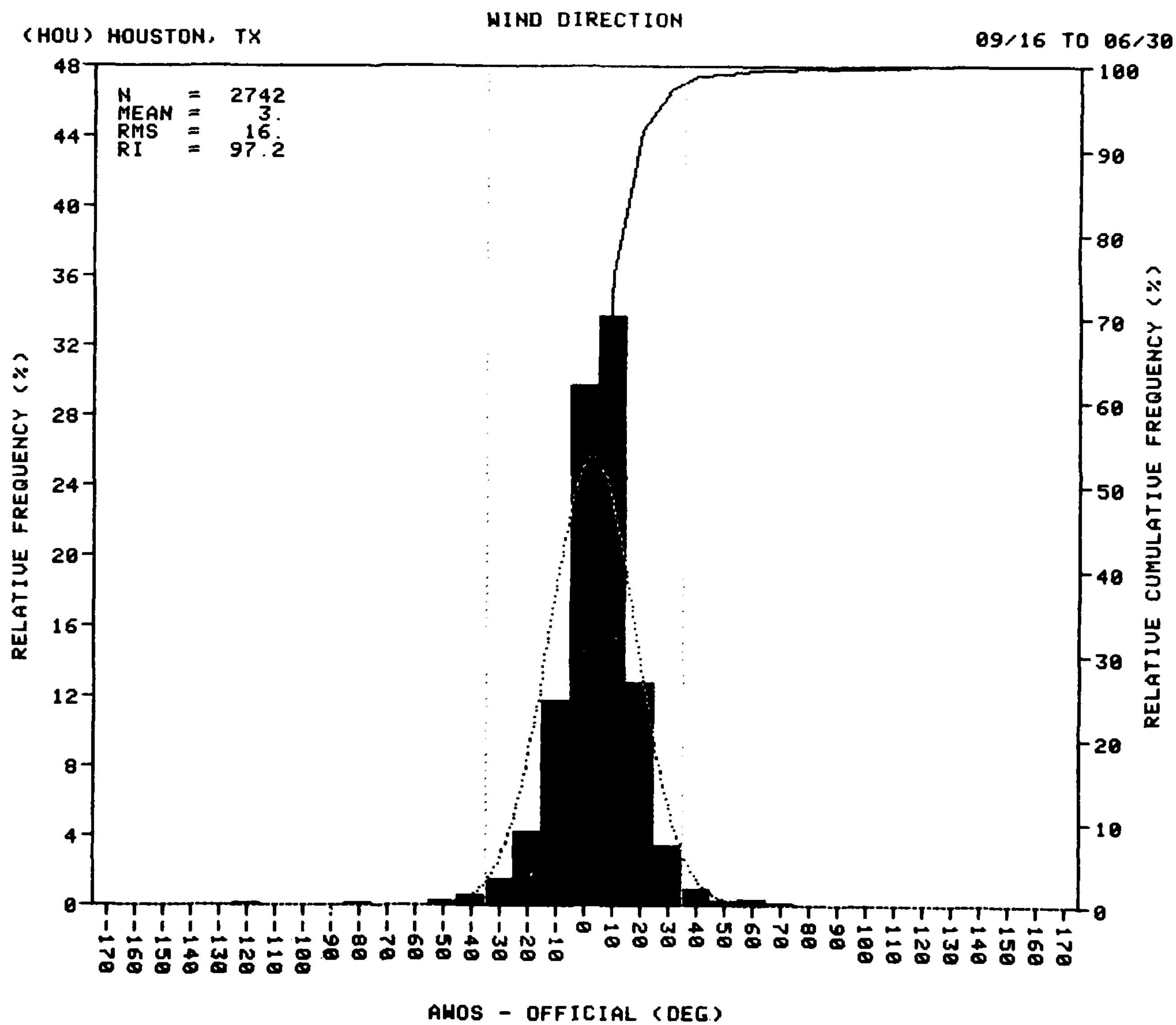

(HOU) HOUSTON, TX
CLOUD HEIGHT
(OFFICIAL > 1500 FT)
09/16 TO 06/30
N = 252
MEAN = 335.
RMS = 884.
RI = 59.9
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (FT)

84-20-D-21b

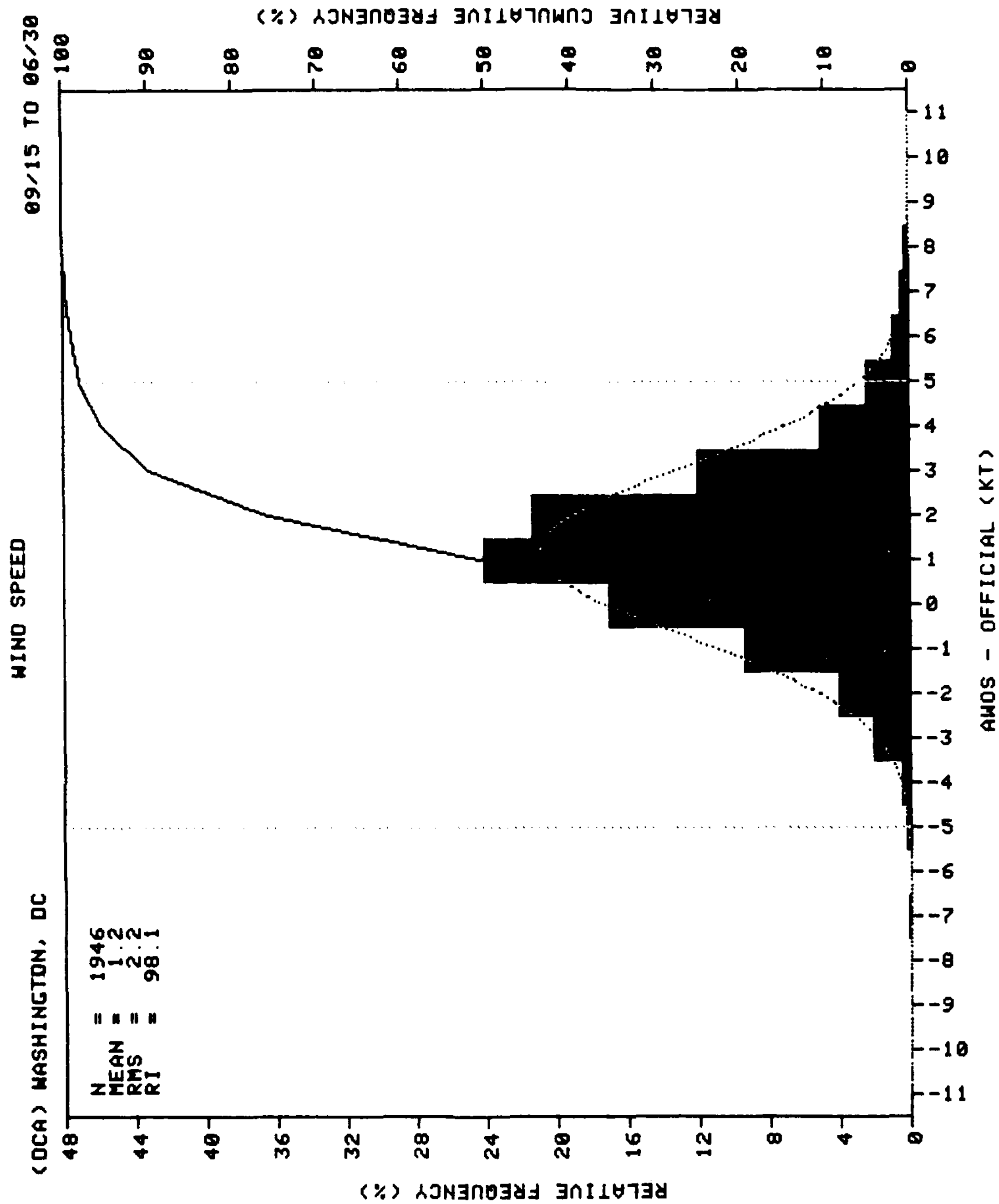

(DCA) WASHINGTON, DC
CLOUD HEIGHT
(OFFICIAL > 1500 FT)
09/15 TO 06/30
N = 159
MEAN = -305.
RMS = 730.
RI = 73.6
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (FT)
72
66
60
54
48
42
36
30
24
18
12
6
0
100
90
80
70
60
50
40
30
20
10
0
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500

84-20-D-21a

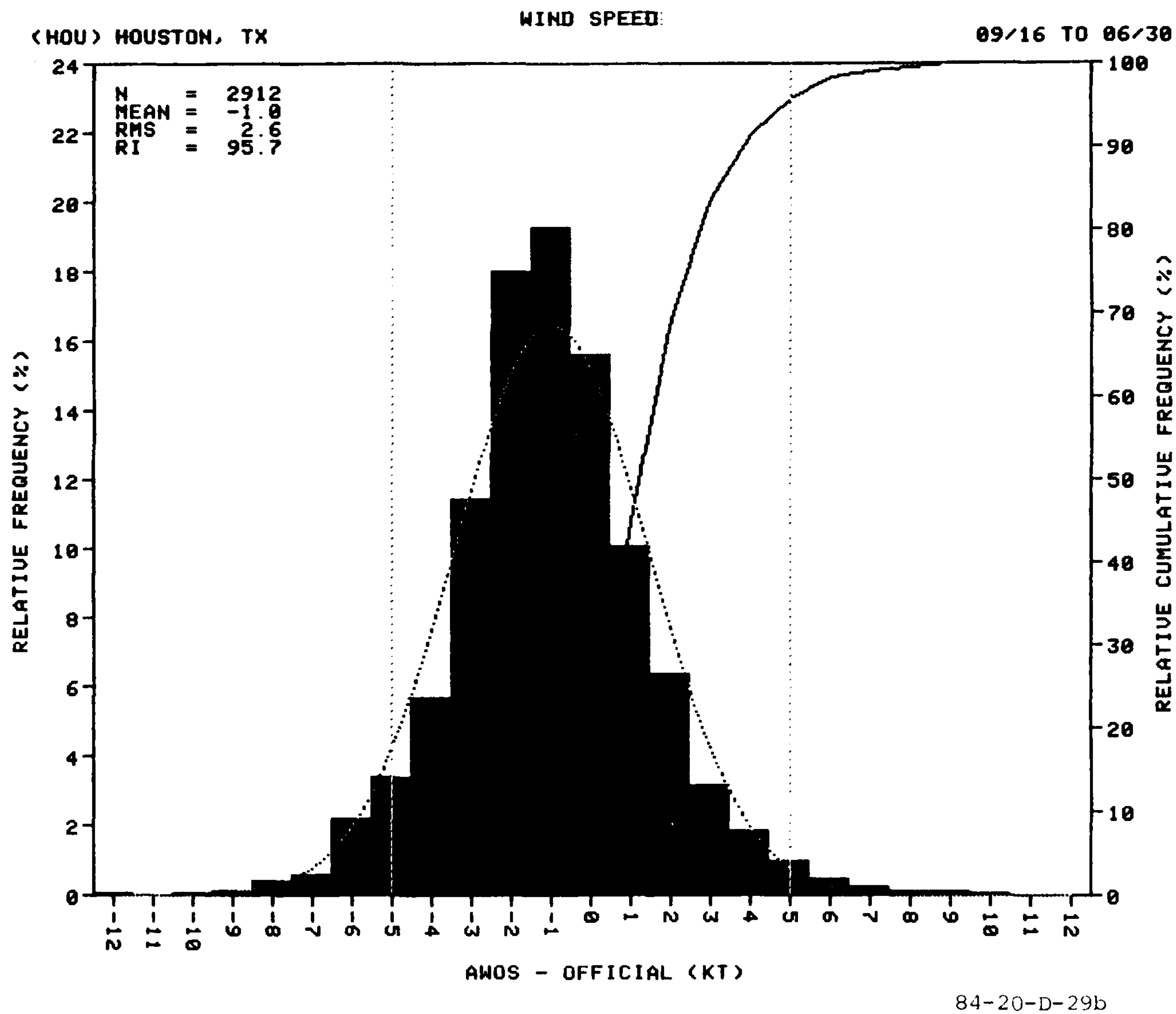

(DCA) WASHINGTON, DC
WIND DIRECTION
09/15 TO 06/30
N = 1945
MEAN = 5
RMS = 18
RI = 96.2
RELATIVE CUMULATIVE FREQUENCY (%)
RELATIVE FREQUENCY (%)
AWOS - OFFICIAL (DEG)
84-20-D-28a

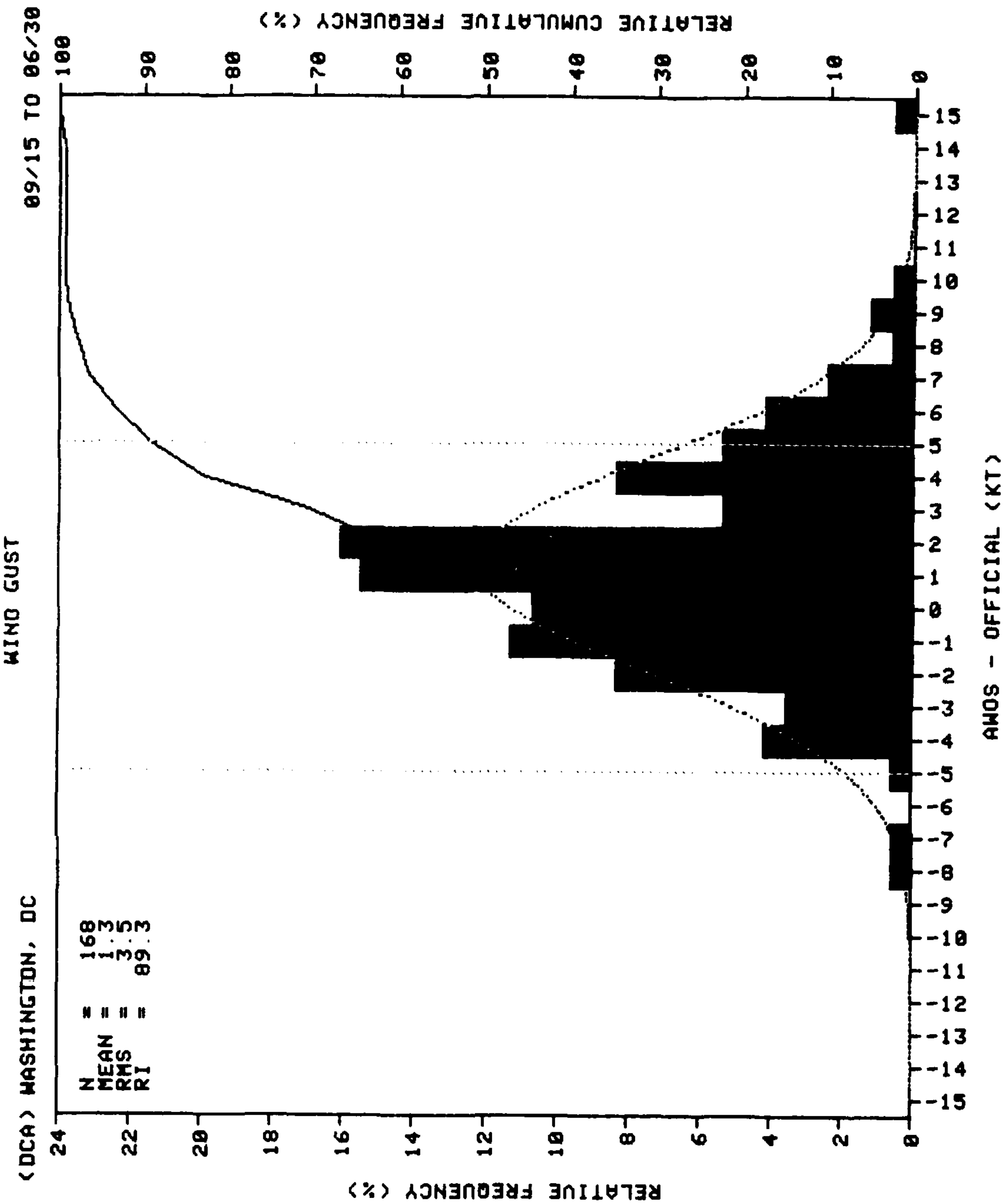

WIND DIRECTION
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 2742
MEAN = 3.
RMS = 16.
RI = 97.2
RELATIVE FREQUENCY (%)
48
44
40
36
32
28
24
20
16
12
8
4
0
RELATIVE CUMULATIVE FREQUENCY (%)
100
90
80
70
60
50
40
30
20
10
0
-170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
AWOS - OFFICIAL (DEG)

84-20-D-28b

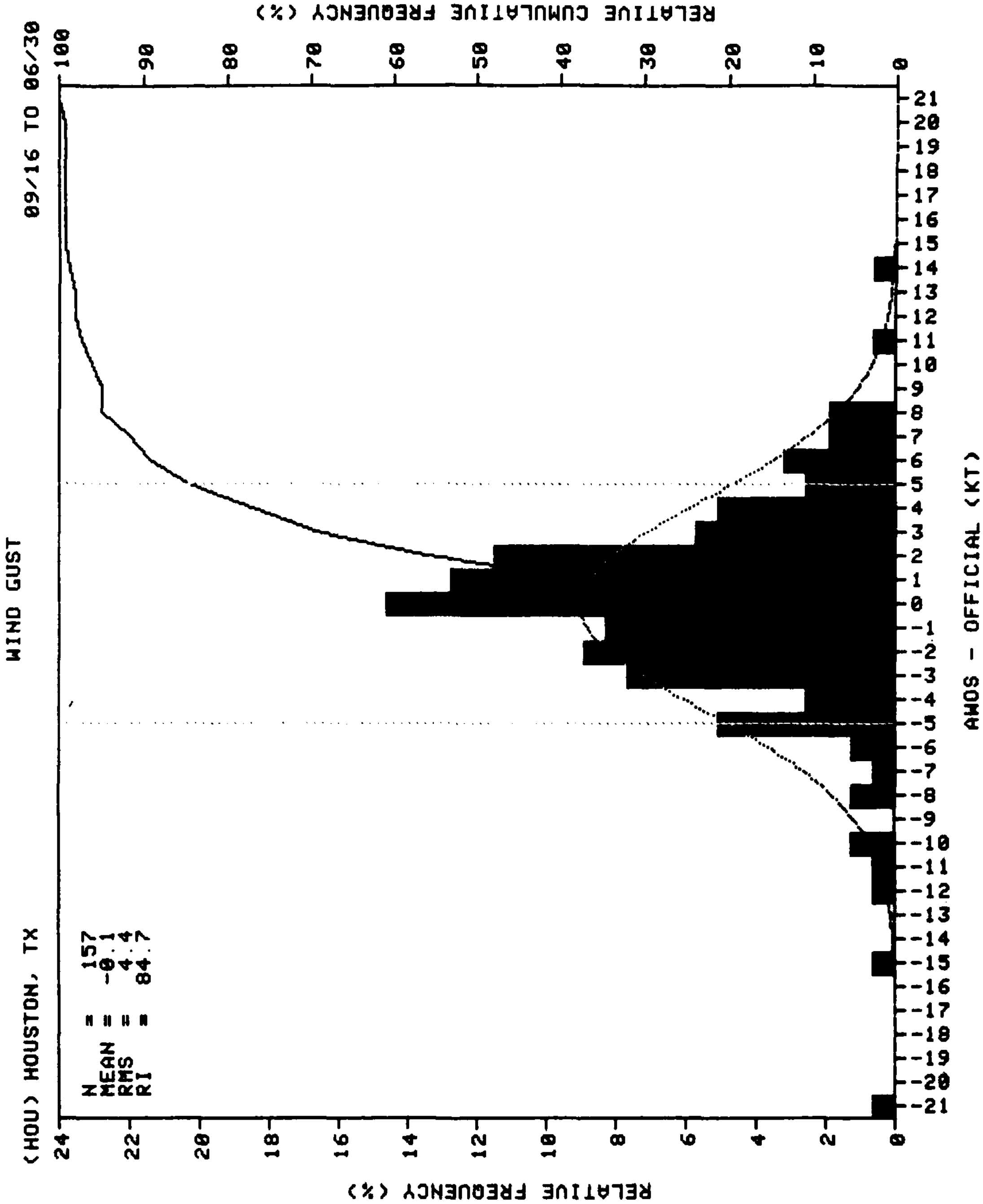

WIND SPEED
09/15 TO 06/30
(DCA) WASHINGTON, DC
N = 1946
MEAN = 1.2
RMS = 2.2
RI = 98.1
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (KT)

84-20-D-29a


WIND SPEED
(HOU) HOUSTON, TX
09/16 TO 06/30
N = 2912
MEAN = -1.0
RMS = 2.6
RI = 95.7
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (KT)
84-20-D-29b


(DCA) WASHINGTON, DC
WIND GUST
09/15 TO 06/30
N = 168
MEAN = 1.3
RMS = 3.5
RI = 89.3
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (KT)
24
22
20
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
-15
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

84-20-D-30a


(HOU) HOUSTON, TX
WIND GUST
09/16 TO 06/30
N = 157
MEAN = -0.1
RMS = 4.4
RI = 84.7
RELATIVE FREQUENCY (%)
RELATIVE CUMULATIVE FREQUENCY (%)
AWOS - OFFICIAL (KT)

84-20-D-30b

END

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6-85

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