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A Demonstration Test of the Modular Automated Weather System (MAWS)

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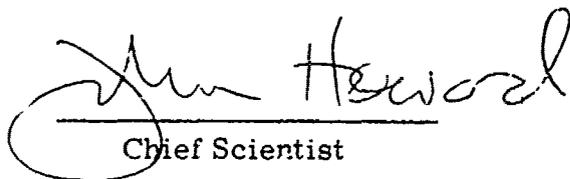
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20. Abstract (Continued)

supervisory microprocessor where the data were suitably collated, averaged and formatted for display on alpha-numeric display devices at key locations and for magnetic tape archiving for post analysis. The demonstration confirmed that modernized weather support can be largely achieved with state-of-the-art, commercially available hardware/software. Such a system would be compatible with other automation efforts in civilian weather services and other C-cubed efforts in the DOD. The advantage of spatially and temporally detailed weather information in marginal and adverse weather situations was documented. Sensor siting considerations were addressed in relation to specific weather elements and observational requirements. The contributions of automated met watch procedures and short-range guidance forecasts of RVR landing minima were demonstrated. Feedback on system performance and acceptability was obtained from cognizant AWS offices.

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Preface

The successful demonstration, test, and evaluation of the Modular Automated Weather System (MAWS) at Scott Air Force Base, Ill., could not have been achieved without the contributions of many individuals at Scott and at AFGL. In particular two former AFGL scientists, Mr. Wayne S. Hering and Captain William R. Tahnk, were instrumental in the project's formulation and implementation. Invaluable technician support was provided by TSgt James Boyce, TSgt Edward Kurbec and Mr. William Lamkin dealing with microprocessor aspects and SSgt Kenneth Wolfe Mr. Ralph Hoar and Mr. John Kierstead with regard to the meteorological sensors. Mr. T. J. Maltacea of AFGL's Research Services Division coordinated logistical support and arranged for the field support of the AFCC at Scott. Of the numerous staff and operations personnel at Scott AFB who contributed to the MAWS effort, Major James Overall, Hq AWS/DN and CMSgt Gerald Sutts and Mr. Paul Quast of AWS/7WW/Det 9 were especially valuable to the program. Lastly, the contribution of Miss Karen Sullivan in typing the manuscript is gratefully acknowledged.

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Contents

1. INTRODUCTION	9
2. DESIGN CONSIDERATIONS	10
2.1 Microprocessor Aspects	10
2.2 Meteorological Sensors	13
2.3 Software Configuration	18
2.4 Software Processing of Meteorological Sensors	19
2.4.1 Ambient (T) and Dewpoint (TD) Temperature	20
2.4.2 Wind Sensors	20
2.4.3 Prevailing Visibility and Runway Visual Range (RVR)	21
2.4.4 RVR Transmissometer	22
2.4.5 Cloud Base Height (CBH)	23
2.4.6 Altimeter Setting	24
3. SYSTEM PERFORMANCE	24
3.1 Hardware	25
3.2 Peripherals	26
3.2.1 Printer	26
3.2.2 Tape Drive	26
3.2.3 Clock	27
3.2.4 Display Device	27
3.3 Software	27
3.4 Communications	28
3.5 Power	29
3.6 Sensors	29
4. DATA ANALYSIS AND INTERPRETATION	31
4.1 Visibility Measures	31
4.2 Wind Aspects	43
4.3 Temperature/Dewpoint	51
4.4 Cloud Base Height	52
4.5 RVR Forecast Model	52

Contents

5. SYSTEM ASSESSMENT	56
6. SUMMARY AND CONCLUSIONS	60
REFERENCES	63
APPENDIX A: MAWS Assessment Form and Responses	65

Illustrations

1. Backplane View of MAWS Microcomputer	12
2. MAWS Display Unit with Detachable Keyboard-Entry Terminal and Power Supply	12
3. MAWS Sensor Configuration at One of Three Runway Observation Sites at Scott AFB	14
4. Location of MAWS and Standard AWS Sensors Relative to Runway 13/31 at Scott AFB	14
5. Schematic Diagram of Forward Scatter Visibility Meter Measurement and Processing Principles	16
6. Schematic Representation of MAWS System Components in Scott Demonstration Test	18
7. Cumulative Frequency Distribution of Sensor Perceived Prevailing Visibility at Each MAWS Location at Scott AFB and the Long-term Climatology of Human Prevailing Visibility (BLV)	32
8. Time-Series Plot of SVR and RVR During Period of Rain at Scott AFB on 4 May 1977	35
9. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 12 Feb 1977	38
10. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 15 Feb 1977	39
11. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 19 Feb 1977	41
12. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 17 May 1978	42
13. Variation of 1-Minute Mean Wind Direction and Speed at Three Runway Locations and the 40-m Tower at Scott AFB on 19 Feb 1977	47
14. Three Episodes of Horizontal and Vertical Wind Shear at Scott AFB on 12 Mar 1977 and 24 Mar 1978	49
15. Time-Series Plot of Sensor Equivalent and Observed Cloud Base Height (CBH) at Scott AFB on 3-4 May 1977	52

Illustrations

16. Probability of Visibility Less Than 1/2 Mile Predicted by RVR Forecast Model vs the Corresponding Relative Frequency of Occurrence (60-Min Forecast)	55
17. Probability of Visibility Less Than 1/4 Mile Predicted by RVR Forecast Model vs the Corresponding Relative Frequency of Occurrence (30-Min Forecast)	55
18. MAWS Demonstration Display Located at Headquarters, Air Weather Service, Scott AFB, Ill.	59

Tables

1. MAWS Sensor Data Collection Efficiency	30
2. Scott AFB Reduced Visibility Correlation Statistics	33
3. Comparison of AWS Observer and MAWS Sensor Equivalent Prevailing Visibility Observations for 27 Episodes	36
4. Correlation Coefficient (R) and Standard Error of Estimation (STE) Between AWS Observations and Time-Averaged, Sensor Equivalent Prevailing Visibility	37
5. Comparative Statistics of Wind Data Reported Manually and Those Reported by MAWS	44
6. Instantaneous Gust Ratios for the Five MAWS Wind Sensors for All Mean Wind Speeds Greater than 4 ms^{-1}	44
7. Wind Speed and Direction Statistics for MAWS Observations at Location R13 vs the Other Four Locations	44
8. Distribution and Cumulative Frequency Distribution (CFD) of Horizontal Wind Shear (HSR) and Vertical Wind Shear (VSR)	46
9. Relative (RFD) and Cumulative Frequency Distributions (CFD) of Crosswind Component (CWC), Wind Gust Spread (WGS), and Wind Gust Spread When the Mean Speed is Greater Than 4 m/sec^{-1} (WGS4)	50
10. Relative (RFD) and Cumulative (CFD) Frequency Distribution of Equivalent Windchill Temperature	50
11. Vertical Temperature Difference, Relative (RFD) and Cumulative (CFD) Frequency Distribution Between R13-T25, R13-T40, and T25-T40	51
12. Brier P-Score Results - RVR Forecast Model	54

A Demonstration Test of the Modular Automated Weather System (MAWS)

1. INTRODUCTION

The basic weather-observing and forecasting-support functions at civilian and military airfields are evolving from a manpower-intensive system to one that increasingly seeks automated solutions that today's technology is capable of providing in potentially more cost-effective ways.¹ Like most of its sister weather services, today's USAF Air Weather Service (AWS) has a clearly stated need for major modernization of its basic weather station support capability. This need is documented in the Automated Weather Distribution System (AWDS) Multi-Command Required Operational Capability (ROC 801-77) which calls for a system which will provide, in part, a fully automated airfield weather-observing and short-range forecasting capability at both fixed-base permanent airfields and at bare-base tactical or temporary airfields.

An exploratory development program was initiated at the Air Force Geophysics Laboratory (AFGL) in 1976 to design, fabricate, test and evaluate an experimental fixed-base automated weather system which relied on operational and/or state-of-the-art weather sensors and the technology provided by the application of micro-processors. Central to the overall program was the fabrication and installation of

(Received for publication 21 March 1980)

1. NOAA-National Weather Service (1979) Aviation Automated Weather Observing System (AV-AWOS), Final Report, FAA-RD-79-63, 131 pp.

a prototype Modular Automated Weather System (MAWS) at Scott AFB, Illinois early in 1977 intended to act as a real-world test bed and demonstration of state-of-the-art technology. The MAWS concept developed around the extensive use of low-cost microprocessors, the automation of the weather sensing or observation function to the fullest extent possible, the application of compact, yet highly visible display devices and communications protocols flexible enough to permit interfacing with and data transmission through several mediums. This report will describe the specific design of the MAWS demonstration prototype and each of its component parts, an evaluation of its demonstration performance, an analysis of the detailed meteorological observations collected at the MAWS locations, and an assessment of the MAWS concept and demonstration as it impacts the proposed acquisition of AWDS.

2. DESIGN CONSIDERATIONS

The Modular Automated Weather System (MAWS) test was conducted to develop and demonstrate the application of microcomputer technology and decentralized computing techniques to the automation of airfield weather observations. The advent of the microprocessor dramatically changed the cost performance constraints within which the electronics system designer had previously worked. The ability to bring microcomputer power to bear on instrumentation problems allowed the substitution of cost-effective digital data processing for much of the complex analog circuitry and cabling encountered in traditional airfield instrument systems. Even earlier digital designs utilizing combinational logic could now be drastically reduced in size, complexity, power requirements, and cost. The output product, airfield weather information, could not only be more accurate and complete but also could include derived information, threshold monitoring, and trends. Through mathematical modeling, this information could provide probability forecasts of visibility, cloud base height, and other desired products.

2.1 Microprocessor Aspects

The Intel 8080A microprocessor was chosen for the MAWS microcomputers for a number of reasons. It was the generally recognized industry standard at that time. It was supported by complete documentation and had immediate availability of principal and compatible secondary components. Its software capabilities included a high-level programming language (PL/M) and a complete software development system. The fact that AFGL personnel were familiar with 8080-type hardware and software made it possible to design, build, and program the demonstration system in minimum time.

In the MAWS demonstration system, printed-circuit cards were developed, each one of which performed a discrete function, such as serial communications interface or data storage. The various computer configurations required by the system could be realized by merely combining the appropriate cards. Additionally, should any card be made obsolete by new developments (which happened repeatedly in early microcomputer days), it could be updated without altering the rest of the system. The principal printed-circuit modules which comprised the MAWS System were:

Central Processing Unit (CPU): Intel 8080A, 2.048 Mhz

Programmable Read Only Memory (PROM): 8K X 8 comprised of 8 Intel 2708, locatable

Random Access Memory (RAM): 2K X 8, comprised of 16 Intel 2111, locatable

Serial Communications: two channel asynchronous, 1200 Baud, RS 232 C

Automated Reset: Develops RESET if no appropriate program activity within selected interval

Magnetic Tape Interface: Kennedy 9000, Read/Write, parallel

Clock, Printer, Common Memory, Bit-parallel/character-serial Chronolog clock-calendar interface: parallel T.I. 810 printer interface, 256 byte, dual port, cache memory

A/D Converter: Converts up to 32 single-ended analog channels to 12-bit binary code. Analog-input ranges switchable under software control

Analog Conditioner: eight-channel signal conditioner configurable to accept all common sensor outputs

Assembly of the several components into a microcomputer, shown in Figure 1, was accomplished in-house, initially using hand-wired versions of laboratory designs. After extensive testing to insure that they met design and performance specifications, detailed drawings were prepared and printed-circuit cards were produced in quantity. From this "family" of cards, a microcomputer can be assembled quickly and economically to meet any requirement.

Burroughs TD 700 terminals (shown in Figure 2) were selected for the system because of features that made them adaptable to the various locations in which a MAWS terminal might be placed. The separable flat display could be hung on a wall with its companion keyboard on a desk and the electronics unit placed out of sight. Since the terminals at Scott were to be placed in already crowded areas, this versatility proved quite valuable. The terminal is configurable for all common communications protocols.

Although a wet-process Versatec printer/plotter was originally supplied with the system for maintenance and system monitoring purposes, it proved unsuitable for infrequent use and unattended operation. Later a dry-process Texas Instrument Model 810 was installed and found to be much more appropriate in this case.

A Kennedy 9000 Series synchronous digital tape recorder was supplied with the system. Its 2400-ft tape provided a nominal capacity to archive approximately

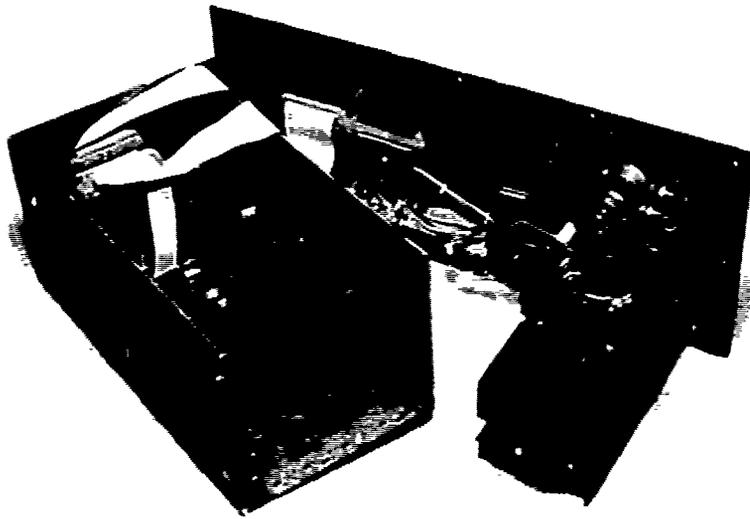


Figure 1. Backplane View of MAWS Microcomputer

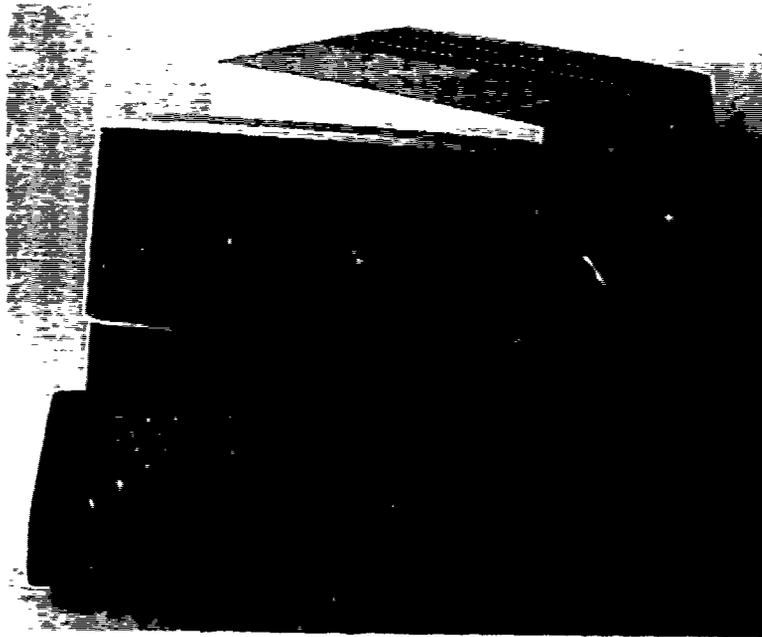


Figure 2. MAWS Display Unit with Detachable Keyboard-Entry Terminal and Power Supply

270 days of processed 1-minute averaged data. This machine has proven itself to be highly reliable in laboratory environments. However, its installation in the relatively unattended MAWS demonstration proved to be a major reason for loss of data because it required manual restart procedures after power interruption.

The communications technique selected for MAWS utilized the Scott AFB commercial-grade telephone system. Transmit and receive pairs from the supervisory microcomputer at Base Weather Station were connected to a conference bridge at the telephone central office. From there, four-wire voice-grade circuits connected both the remote microprocessors (for data acquisition) and the alphanumeric terminals (for output dissemination). "Poll and Select" communications protocol separated inputs from outputs. With this method, all stations, both data points and terminals, are always "listening" to the supervisor's output. Transmissions intended for individual stations are uniquely addressed to that station. All output terminals were addressed simultaneously using "Broadcast" mode. Tailored transmissions to individual terminals could have been selected if desired.

2.2 Meteorological Sensors

The research and development demonstration of MAWS at Scott Air Force Base was seen as a twofold opportunity. The first was to evaluate the automation of appropriate standard operational weather sensors. The second was to subject several state-of-the-art sensors used in earlier R&D efforts by AFGL to extended evaluation in an operational environment. Among the operational sensors deployed at Scott AFB, the transmissometer (AN/GMQ-10) and rotating-beam ceilometer (AN/GMQ-13) were identified for inclusion in the MAWS demonstration. State-of-the-art sensors which were used included the EG&G Model 207 Forward Scatter Visibility Meter (FSM), the Climatronics Mark I Wind Sensor, the EG&G Model 110S-M Automated Temperature and Dewpoint Set, and the Sperry Digital Altimeter Setting Indicator (DASI). Figure 3 shows the deployment of MAWS sensors at a 4-m height along the Scott runway and Figure 4 is a map of Scott AFB which denotes the locations of MAWS and AWS sensors.

The selection of a scattering-type sensor to obtain visibility measurements was predicated on our experience with and preference for a site configuration consisting of sensors mounted on a single telephone pole for surface-based measurements and an aluminum-frame upright tower for elevated measurements. The advantage of scattering meters over transmissometers is due to their single-frame construction which eliminates alignment problems and facilitates installation on poles and towers.

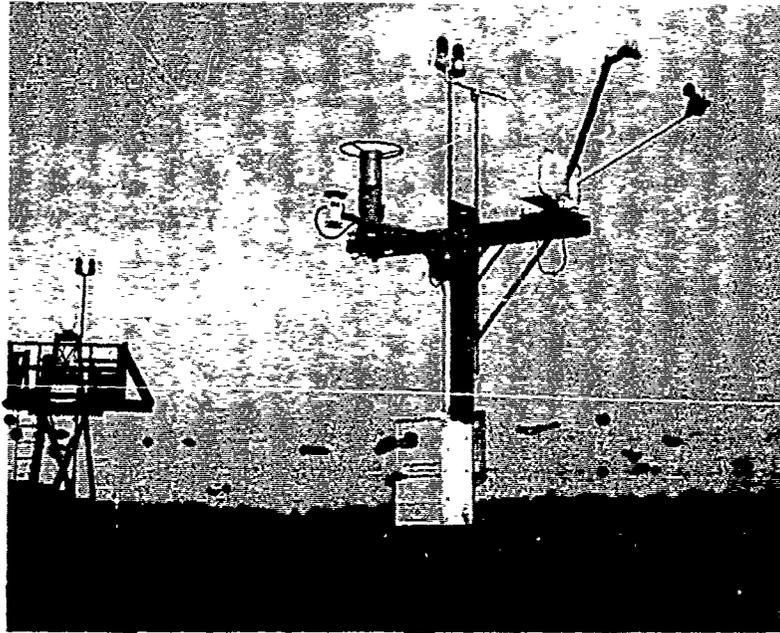


Figure 3. MAWS Sensor Configuration at One of Three Runway Observation Sites at Scott AFB

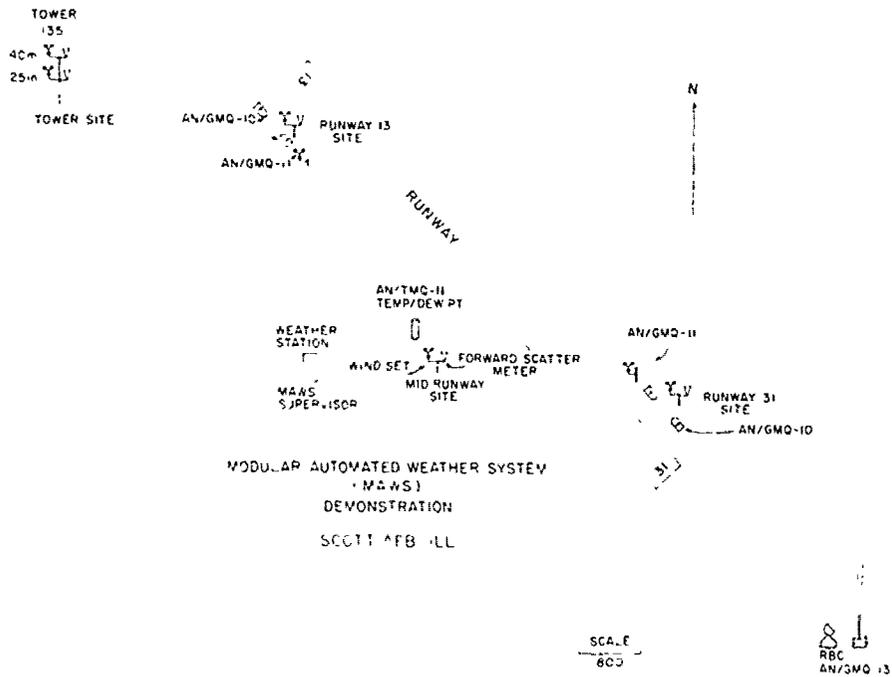


Figure 4. Location of MAWS and Standard AWS Sensors Relative to Runway 13/31 at Scott AFB

The FSM was selected for the Scott MAWS demonstration based on several years of extensive testing^{2, 3} which has demonstrated that the FSM provides reliable, accurate, and representative measurements of atmospheric extinction coefficient and visibility. The FSM selection was also based on comparative tests of the FSM, candidate backscatter, and total scatter sensors.⁴

The FSM is a short-path-length visibility instrument which consists of a projector and receiver mounted in a single frame structure. The sensor design (see Figure 3) minimizes the likelihood of heat plumes rising from the control unit into the sampling volume and modifying the measured extinction coefficient. Figure 5 is a schematic illustration of how the FSM operates. The projector consists of a halogen lamp operated by a 120-V, 60-Hz regulated power supply. The projected light beam is mechanically chopped before entering the optical system, which projects a cone of light. A photodiode monitors the light, providing both feedback to the power supply and timing information to the receiver circuitry. The receiver is mounted and aligned with the projector at a separation distance of about 1.2 m. It consists of a photodiode that receives light from a cone-shaped volume similar to that of the projector. Both the projector and receiver sampling volume have an inner cone masked out to prevent direct-light transmission. The intersection of the projected and viewing cones forms a sampling volume of 0.05 m^3 (indicated by the stipled area in Figure 5), which contains light scattered forward over a range of 20 to 50° by particulates and/or aerosols within the volume.

The sensor provides voltage output in a 0- to 5-volt range in either a single linear or two logarithmic output ranges. In the MAWS demonstration, the two-channel, log-amplified output option was used. The procedures used for converting voltage output to extinction coefficient and then to visibility/RVR values are discussed in Section 2.3.3.

The Climatronics Mark I Wind Sensor was selected for the MAWS demonstration based on prior research experience and on the fact that a sufficient number of operational wind sensors (AN/GMQ-20) could not be made available to us for the duration of the demonstration. One AN/GMQ-20 was obtained for the purpose of designing and fabricating a microprocessor interface which would permit digital display of wind direction and speed. This was achieved through the use of an off-the-shelf synchro-to-digital converter, a single-chip microprocessor unit and its

2. Hering, W.S., Muench, H.S., and Brown, H.A. (1971) Field Test of a Forward Scatter Visibility Meter, AFCRL-TR-71-0315, AD 726 996, 19 pp.
3. Muench, H.S., Moroz, E.Y., and Jacobs, L. P. (1974) Development and Calibration of the Forward Scatter Visibility Meter, AFCRL-TR-74-0145, AD 783 270, 37 pp.
4. Chisholm, D.A., and Jacobs, L. P. (1975) An Evaluation of Scattering-Type Visibility Instruments, AFCRL-TR-75-0411, AD B010 224L, 31 pp.

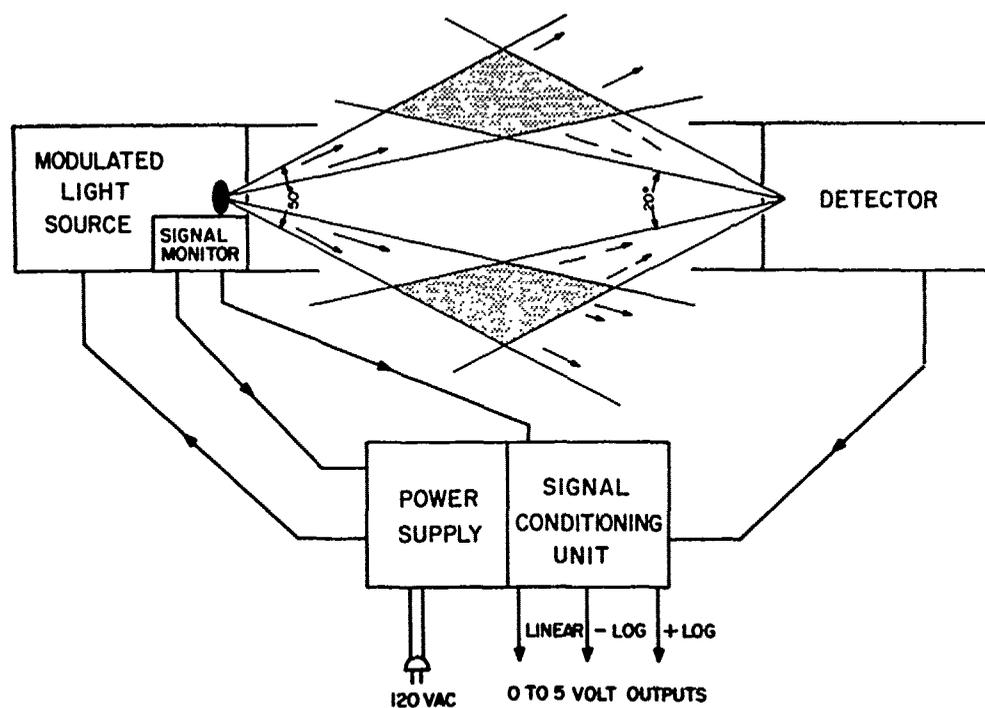


Figure 5. Schematic Diagram of Forward Scatter Visibility Meter Measurement and Processing Principles

associated programmable and random access memories, an AC power supply, and a simple 20-character alpha-numeric display device.

The Climatronics cup-and-vane wind sensor is lightweight, has low power consumption, and a low start-up threshold (0.22 m s^{-1} for speed and 0.11 m s^{-1} for direction). It also responds quickly and is very accurate (for wind speed, ± 1 percent or $\pm 0.7 \text{ m s}^{-1}$, whichever is greater, and for direction $\pm 2.5^\circ$). Sensing is achieved with a non-contacting, wind-direction transducer and a chopped solid-state light source for speed. The instrument operates on a 0° to 540° direction range which automatically accounts for crossover problems (for example, 360° to 0°).

Temperature and dewpoint observations were obtained with the EG&G Model 110S-M Automatic Temperature and Dewpoint Set. The set had been used extensively in previous research studies, and procedures already existed for automatic interface to a data system. Automation of the Scott operational sensor, AN/TMQ-11(V) located near the MAWS mid-runway site, was investigated and rejected based on several factors. These included the complexity and cost of the modification, the need to disrupt and disable the operational sensor to effect the modification,

and the need for additional sets for the other MAWS locations. The EG&G Temperature-Dewpoint set has a range from -62°C to 49°C , with accuracies over the range of interest of about $\pm 0.25^{\circ}\text{C}$. Air temperature is determined with a platinum resistance thermometer which is thermally shielded and aspirated. The dewpoint measurement is obtained using a Peltier-cooled mirror automatically held at the dewpoint temperature by means of a condensate-detecting optical system. The mirror or dewpoint temperature is then determined by an embedded platinum resistance thermometer similar to the one used for air temperature.

Several commercially available digital altimeter setting devices were available for consideration in the MAWS demonstration. After subjecting three of them to bench testing and limited field testing at AFGL, the Sperry Digital Altimeter Setting Indicator (DASI) was selected based on its rugged, durable design and highly accurate and reliable test performance. It has a very sensitive vibrating diaphragm to sense atmospheric pressure, which is automatically converted to the airfield's altimeter reading, given the proper specification of station elevation.

The standard AWS visibility-measuring equipment (AN/GMQ-10B) measures atmospheric transmission of light along a fixed path of 150 m in length parallel to the airfield runway. The sensor output is an accumulated pulse rate which is proportional to the percentage of the projected light beam received at the detector. The received pulse count is then converted to extinction coefficient and visibility by software as described in Section 2.3.4. With a 150-m baseline, the transmissometer has an effective visual range of 0.2 km to more than 10 km. The integration of the GMQ 10B into the MAWS processing stream was achieved beyond the switching-mechanism point. This allowed only signals from the active runway transmissometer to enter the MAWS supervisory computer.

The standard AWS cloud-height set (AN/GMQ-13A) was the only candidate sensor available for cloud-height measurements in the MAWS demonstration. It consists of a dual, tungsten-filament projection system, modulated at 120 Hz and rotated at 5 rpm. The receiver, which is normally set about 120 m from the projector, has a vertical field of view, coplanar with the rotating projector beam. The sensor's intersection volume advances up the detector's vertical beam as the projector's beam rotates from the horizontal. When it intercepts clouds, light is backscattered, resulting in an intensified signal in the detector's lead-sulfide photoconductive cell. The 5-rpm rotation speed of the dual-lamp design results in a measurement sweep every 6 seconds. The effective sampling range, given a 120-m baseline, is 15 m to 1450 m. A solid-state photocell amplifier, previously subjected to considerable test and evaluation by AFGL, the FAA, USN, and Canadian Atmospheric Environment Service, was installed in the Scott GMQ-13's as part of the MAWS effort in an attempt to minimize the impact of broadband noise on the automation procedures. Here again, MAWS only obtained signal data from

the active runway sensor to insure maximum compatibility between its observations and the operational observations.

2.3 Software Configuration

Figure 6 is a schematic representation of the MAWS system at Scott AFB. Remote microprocessors (RM) were deployed at each of the four sites with a supervisory microprocessor (SM) located in the Scott Base Weather Station (BWS). Since the RM's had no time base of their own, they only acquired, processed and transmitted data when the SM sent out the appropriate command. The SM sent out these commands every 12 seconds for each RM to sample ambient temperature, dewpoint temperature and visibility, and every 6 seconds to sample wind quantities. Automated edit and self-test procedures were utilized in examining the data from the sensors to insure that erroneous data did not go undetected. Once a minute the processed data from each RM was then relayed, on command, to the SM at a rate of 120 characters per second.

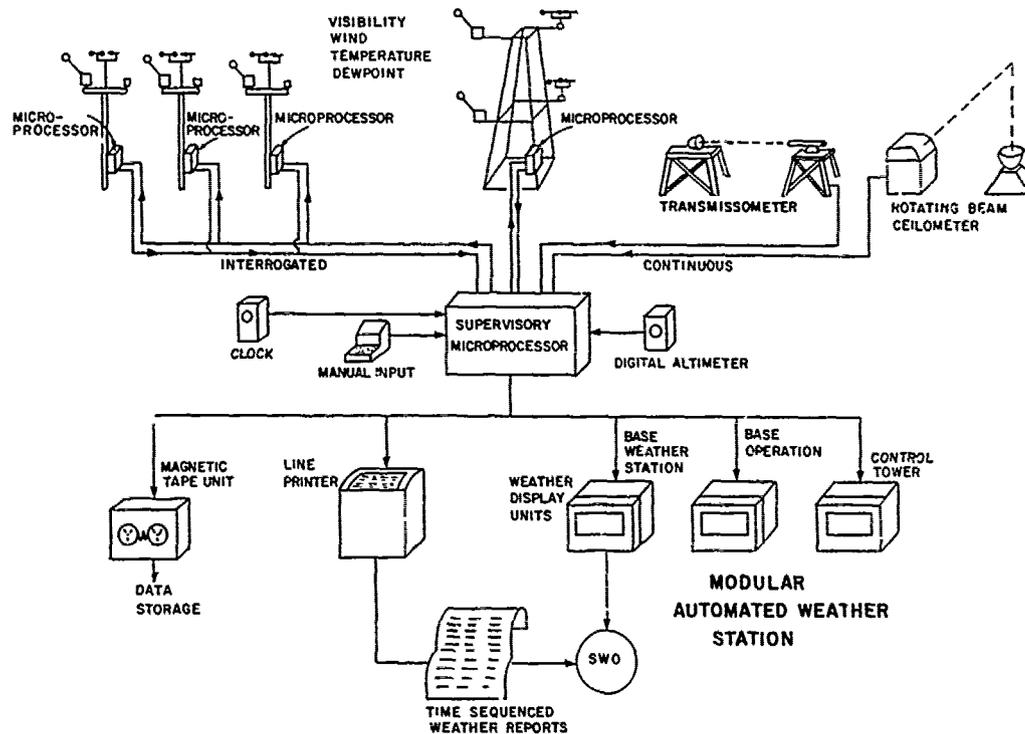


Figure 6. Schematic Representation of MAWS System Components in Scott Demonstration Test

The SM was the heart of the system, controlling the flow of all processed information and raw data. In its role as the system manager, the supervisor disseminated and archived all the parameters after accomplishing further processing and editing of the RMs' data. In addition, the SM interrogated several sensors directly. These were the ceilometer for cloud detection, the standard transmissometer for runway visual range, the digital altimeter setting indicator, and the digital clock/calendar. The sensor data received by the SM, either directly or through the RMs, were disseminated on a real-time basis in several ways. Alpha-numeric display units were placed in a prominent position in Air Weather Service (AWS) Headquarters and in the BWS. These display units were updated continuously and provided a means to monitor most of the weather parameters. A description of the four pages of display routinely generated by MAWS has been documented previously⁵ and will not be repeated here. In addition to the displays, a printer was installed at the BWS so that the operator could obtain a hardcopy of any or all parameters. The printer was also used in a maintenance function to check the accuracy of the sensors. Finally all observed parameters were archived on magnetic tape once per minute.

Many of the tasks handled by MAWS were made flexible by allowing an interactive capability. An operator could change various options by making manual inputs to the system via front-panel switches on the SM. One option allowed the operator to take one sensor or even an entire location out of the routine processing stream in the event of questionable data from a sensor or sensors until repairs could be made. This could be done without influencing the rest of the system. Another option allowed the operator to get a hardcopy of the current minute's observation very similar in format to the way observations are currently sent through the Automated Weather Network (AWN). In addition to the observation, a hardcopy of the forecast could be obtained through another option. The operator could also request a hardcopy of the RVRs, winds, or temperatures from one sensor, one location, or from all locations. From this data the operator could produce a vertical and horizontal distribution of certain parameters around the airfield. Other options included the ability to display readings in metric or English units, to account for changes in active runways, to prepare for a tape change, to query individual RBCs, and to retransmit display headings when necessary.

2.4 Software Processing of Meteorological Sensors

With the exception of the digital altimeter and transmissometer each sensor used in the MAWS demonstration produced an analog signal. In each case the

5. Tahnk, W. R., and Lynch, R. H. (1978) The Development of a Fixed Base Automated Weather Sensing and Display System, AFGL-TR-78-0009, AD A054 805, Instrumentation Papers No. 260, 21 pp.

signal was channeled into the microprocessor through a signal conditioner and then passed to a converter which changed the analog signal to a digital form. While the converter was capable of resolving one part in 4096, in most cases this precision surpassed that of the instrument; thus only the most significant 8 bits or one part in 255 were used. The Intel software was written in PL/M-80 which is only capable of processing positive integers. This necessitated resorting to internal manipulations (for example, multiplications by powers of 10) in order to maintain desired accuracy.

A description of the processing of each instrument is provided in subsequent sections.

2.4.1 AMBIENT (T) AND DEWPOINT (TD) TEMPERATURE

The T and TD sensors were sampled once every 12 seconds by the RMs. The analog signal was converted to a digital value with a resolving capability of one part in 255. This yielded an accuracy of $\pm 0.40^{\circ}\text{C}$ which is near the accuracy of the instrument. Once a minute, the average of the digital values was computed and converted to a Fahrenheit temperature to the nearest whole degree. The 1-minute average T and TD from each site were transmitted to the SM on command. The T and TD from the active end of the runway were continuously displayed and used to calculate relative humidity and equivalent windchill temperature. Each minute, the temperature from the active end of the runway was also compared with the maximum and minimum temperature for that hour, which would then be adjusted, if required. At the end of each hour, the 24-hour maximum and minimum value would be compared to the present hour's value and updated if necessary.

2.4.2 WIND SENSORS

To formulate 1-minute mean wind speed and direction, the wind sensors at each site were sampled once every 6 seconds. The resolving capability of the converter was one part in 255 which yielded an accuracy of $\pm 0.18 \text{ m s}^{-1}$ for speed and 2.1° for direction. As each sample was acquired in the RM, the wind vector was broken down into u and v components. At the end of a minute, the averaged u and v components were translated back into wind direction (to the nearest degree) and into wind speed (to the nearest knot). In addition to the 1-minute mean values, the RM sampled the wind speed continually (as often as 1000 times per second) to obtain a maximum instantaneous wind speed. These values were then transmitted back to the SM where the latest 1-minute maximum instantaneous value was compared to the previous four maximum readings to obtain the maximum instantaneous value over the last 5 minutes. The 1-minute mean wind speeds (in knots), the 1-minute mean directions (in 10's of degrees), and the 5-minute maximum instantaneous wind speeds from the active end of the runway, 25-m level, and 40-m level were continuously displayed. The wind vector from the active end of the

runway was also used to calculate crosswind, equivalent windchill temperature, and gust spread (difference between maximum instantaneous wind gust over the last 5 minutes and the latest 1-minute mean wind speed). In addition, horizontal wind shear was computed as the vector difference between the wind at each end of the runway, and the vertical wind shear was computed from the vector difference between the runway site at R13 and upper-tower winds.

2.4.3 PREVAILING VISIBILITY AND RUNWAY VISUAL RANGE (RVR)

The FSM used in this demonstration produced a two-channel logarithmic analog output. Both channels were sampled once every 12 seconds. Validity and comparative tests were performed and the readings were combined into a single value with a resolution of one part in 512 over the 10-volt range (5-volt negative channel and 5-volt positive channel). Once a minute the RM transmitted the average atmospheric extinction coefficient to the SM. The SM then calculated an RVR value for each FSM and one value of sensor equivalent prevailing visibility. The prevailing visibility, the current RVR values from R13, R31, 25 m and 40 m, and the minimum and maximum RVR values during the past 10 minutes for each of the four sites were routinely displayed. This provided a three-dimensional display of RVR around the airfield. In addition, the active runway RVR was used as an input to the probability forecast equation discussed in Section 4.5.

The instrument equivalent prevailing visibility was determined from the atmospheric extinction coefficient reported by the FSM at the 25-m level of the tower. MAWS was being considered as an automated weather observing system which could potentially remove the requirement for human observers. As such, the calculated prevailing visibility was intended to simulate that which a person in the control tower would perceive. Under daytime conditions, the extinction coefficient can be used in Koschmieder's Law⁶ with the contrast threshold of 0.055 to prescribe a daytime instrument equivalent prevailing visibility. At night Allard's Law⁶ applies. It states that the visual range is the distance at which light will produce a fixed illuminance threshold

$$E_T = \frac{I}{V_r^2} e^{-\sigma V_r} \quad (1)$$

6. Middleton, W. E. N. (1952) Vision Through the Atmosphere, University of Toronto Press, Chaps 6-7.

where E_T is illuminance threshold, I is light intensity, V_r is visual range, and σ is extinction coefficient. However, Douglas and Booker⁷ found that a somewhat different relationship agreed better with experimental data. They proposed an equation in which the illuminance threshold (S) varies inversely with the visual range

$$S = \frac{I}{V_r} e^{-\sigma V_r} \quad (2)$$

In this equation, S has dimensions of intensity per unit distance and is expressed as cd mi^{-1} . Douglas and Booker⁷ found a value of 0.084 cd mi^{-1} for S corresponding to a light intensity value of 25 cd. It was this relationship (Eq. (2)) which was utilized in the MAWS model along with the 25-m FSM value to determine the sensor equivalent prevailing visibility at night. The displayed prevailing visibility ranged in value from 0.06 to 10+km in increments of 0.02 km between 0.06 km and 0.20 km, 0.08 km between 0.20 km and 0.8 km, 0.16 km between 0.8 km and 3.2 km, 0.8 km between 3.2 km and 4.8 km, and 1.6 km between 4.8 km and 10 km.

The daytime sensor RVR was initially determined from each FSM's extinction coefficient using Koschmieder's Law and a contrast threshold of 0.055. However if the calculated RVR was less than 1200 m or it was night, Allard's Law was applied using a light intensity of 10,000 cd (runway light setting 5) and an illuminance threshold of 2 cd mi^{-2} at night and 1000 cd mi^{-2} for daytime conditions. The reported RVR ranged from 0.15 to 10+km in steps analogous to the prevailing visibility intervals.

2.4.4 RVR TRANSMISSOMETER

The operational AWS transmissometer produces a pulse rate output. This output was sampled by the SM once every minute and transformed into units of atmospheric extinction coefficient. Each minute the RVR was computed by one of two methods. During the daytime (with RVR greater than 1200 m) the system used Koschmieder's Law with a contrast threshold constant of 0.055 to compute RVR based on the transmissometer baseline of 153 m. During the daytime with RVR less than 1200 m and at night, Allard's Law was used to compute RVR. A light intensity of 10,000 cd (runway light setting 5) and an illuminance threshold of

7. Douglas, C.A., and Booker, R.L. (1977) Visual Range: Concepts, Instrumental Determination, and Aviation Applications, NBS Monograph 159, 362 pp.

2 cd mi⁻² was used at night and 1000 cd mi⁻² was used for daytime. The transmissometer RVR values were not displayed in real time but were archived.

2.4.5 CLOUD BASE HEIGHT (CBH)

The integration of the Rotating-Beam Ceilometer (RBC) into MAWS was by far the most complex interface and automation problem encountered. The rectified and filtered DC signal from two RBCs had to be acquired, processed, and analyzed automatically and continuously without affecting the AWS observer's manual determination of the cloud base height. In addition, the hardware and software had to be generalized enough so that it would be applicable to any RBC and any lamp. The resultant hardware interface successfully established a background level from each 90° scan of the source lamp and provided for automatic gain and offset adjustment under software control.

The normal 90° scan of each RBC was divided into 360 distinct bytes of data, each representing 0.25° of elevation. After the 0° switch-closure signal was received at the microprocessor, readings were made every 8.3 msec, which equated to every 0.25°. The converter resolving capability was one part in 255 over the 5-volt range output. The 90° scan was broken into four parts. The first 5° were used to calculate the gain adjustment, 5 to 85° were taken as data, 85 to 86° were used to calculate offset adjustment, and the last 4° were ignored.

The first 5° were used to calculate the gain adjustment because the large start signal was located here. This signal was produced when the transmitter's light was reflected directly into the receiver by a small metal plate on top of the receiver. If the received signal was less than the maximum value of 5 volts, the signal was amplified using one of four possible gains: 1.00, 1.25, 1.30, or 1.55.

The 85° and 86° readings were used each scan to determine the noise level from which to calculate an offset for the next scan. At these elevation angles, returns consisted of noise without real signal. The noise level obtained from the current scan was then combined with the readings from the previous nine scans to determine an averaged offset adjustment. The maximum adjustment or offset allowed was 1.176 volts, with successively lower values possible in steps of 0.074 volts. This procedure was invoked for the purpose of suppressing the noise of the system below the recognition level, thereby maximizing the detection of real cloud signals.

The data from the 5° to 85° readings were temporarily stored away until all were accumulated and then analyzed, filtered, and averaged. The first step was to eliminate any sharp noise spikes by comparing individual data points with values on each side of it. If the center value was three times larger than the average of its immediate neighbors, the value was discarded and an average of the

side values replaced it. The second step was to apply a weighted average filter to the data. The weights were 1, 6, 15, 20 for the $n \pm 3$, $n \pm 2$, $n \pm 1$, and n data points respectively. Next, the relative peaks were identified, where a peak was defined by at least three ascending values, followed by at least one descending value. From these peaks, the one with the largest magnitude was located and the appropriate height bin annotated. There were 80 height bins representing the 80° sampled.

The software logic limited consideration to just one of the two RBC lamps in any one minute, thus one such trace was acquired every 12 seconds. A representative cloud base height was determined in the following manner from the five separate scans obtained each minute. If two of the five height bins were equal and a match was not found at a lower height, this height was chosen as the CBH. If there was not a match among the five values, the bins were compared again to determine if two bins were within plus or minus two bins of each other. If more than two bins met this criteria, the lowest height bin was chosen. If the first two conditions were not satisfied, a third check was made which compared all five bin values with the CBH reported the previous minute. If any of the values were within plus or minus two bins of the previous CBH, then this bin value was chosen. If all three checks failed, a final test was made to determine if an obscuration existed by evaluating the overall noise level in the 5° to 85° range.

In summary the CBH which results from the preceding logic was one of the following:

- a. an obscuration
- b. a reportable cloud base ranging from 15 to 1450 m for a base line of 153 m
- c. no reportable cloud base

The CBH was then displayed and also was an input to the probability forecast equations.

2.4.6 ALTIMETER SETTING

The digital altimeter setting indicator (DASI) used in the MAWS produced a digital signal unlike the analog signals of the other instruments. The output was to the nearest 0.01 inches of mercury, and the sensor was sampled once a minute. The 1-hour sea-level pressure and the 1-hour change in sea-level pressure, reported in tenths of millibars, were computed from the hourly altimeter setting using a standard barometric formula.

3. SYSTEM PERFORMANCE

The only means by which the MAWS system performance could be quantitatively evaluated was through an examination of the collection efficiency of the magnetic

tape system. As will be detailed in subsequent paragraphs, one of the weaker links in the largely unattended mode of operation attempted at Scott was the magnetic tape subsystem. Although impossible to document, we were able to establish qualitatively that the dissemination and display components of MAWS generally were operating properly during many tape-archiving interruptions. In an absolute sense, the system only archived data on tape about 40 percent of the 2-year period. There were, in fact, several periods which individually lasted many days to several weeks during which the system was inoperative or data were lost due to telephone central office problems, tapes lost in transit from Scott to Hanscom, and tape rewind followed by rewrite over previously recorded data. After accounting for all such known "losses", the overall collection efficiency for the rest of the 2-year period was found to be about 75 percent of the time. AFGL, by necessity, did not have personnel on-site at Scott monitoring the system. Rather, we relied on the cooperation and assistance of AWS personnel at Scott to advise us of system malfunctions and to restart the system under certain conditions. Budgetary constraints for travel purposes limited our timely response to problems in many instances, thereby aggravating the periods of system "downtime". The problems which led to the system's temporary inoperation can be conveniently grouped into the following categories for further discussion:

- a. Hardware
- b. Peripherals
- c. Software
- d. Communications
- e. Power
- f. Sensors.

Most of the problems were encountered once, were corrected, and did not recur.

3.1 Hardware

Microprocessing hardware represented the most reliable aspect of the MAWS system. Occasionally, some of the IC chips in MAWS were ruined by lightning strikes in close proximity to the computer, and by power surges on the line. A more bothersome problem was the behavior of the MAWS system when the outside air temperature exceeded 32°C. Cooling fans were used at all remote data unit locations to control the internal temperature of the microprocessor equipment enclosures. Unfortunately, clogged vents and filter screens in the fan assemblies often severely restricted the circulation of outside air through the enclosure. Periodic replacement/cleaning of the screens and vents alleviated this problem after it was finally recognized. At least one commercial-grade component on the

communications interface card is sensitive to high temperatures, with the result that communications with the supervisor were intermittently interrupted. Developing technology which satisfies military specifications, but not integrated into the MAWS design, would reduce or eliminate this problem in future designs even without the use of fans.

3.2 Peripherals

3.2.1 PRINTER

Initially this category was one of the more troublesome areas for MAWS data collection, and understandably so, since we were relying on mechanical devices operating continuously in an unattended mode of operation. The printer originally used in the MAWS system was a Versatec wet-process printer. It frequently experienced clogged tubes, which resulted in dumping of the solution on the floor. This particular problem did not directly affect the data collection on magnetic tape. However, the printer was intended to be used to detect systematic errors in selected sensors on either a one-time or continuous basis. Hence, during printer outages, systematic errors went undetected, rendering useless some of the archived data. This problem was corrected by changing to a high-speed, dry-process impact printer which proved to be ideal in the unmanned MAWS environment.

3.2.2 TAPE DRIVE

Tape drives tend to be especially sensitive to external influence. Clearly, the performance of the tape drive was the most critical aspect of MAWS in terms of data collection. It should be pointed out, however, that its failure was often a singular problem not affecting the other components of the MAWS dissemination and display capabilities. The following is a list of external occurrences experienced by MAWS and the corresponding effect each had on the tape drive:

- a. A supervisor reset created two effects, an end of file being written on tape or the tape drive switching from write mode to read mode and rolling forward unimpeded.
- b. Fluctuations in power to the tape drive resulted in the same effects as in a. above if the fluctuation was of short duration (under 100 m/sec). If the fluctuation was of longer duration, the tape drive switched out of record mode and data archiving ceased.
- c. Loss of power to the supervisor resulted in the tape rolling forward unimpeded until power was restored.

The summer months at Scott AFB are characterized by frequent periods of thunderstorm activity. This, in turn, leads to power fluctuations, power interruptions, and the use of back-up generator power, all of which can lead to

occurrences a. through c. above. In addition, one tape containing over 4 months of data was unreadable due to unrecoverable parity errors and another containing 2 months of data was lost in transit between Scott and Hanscom.

A rewind-on-power-down problem, which plagued the early part of the demonstration, was corrected in June 1977, thereby increasing the data collection rate subsequent to that date. If the supervisory computer and the tape drive could have been on uninterruptible power, the rest of the data loss problems would also have been corrected. Unfortunately, this was not practical at the time, so alternative solutions had to be found. Finally, changes elsewhere in the system yielded a drastic reduction in the number of times the supervisor resets the system, so that the data collection rate later in the period was much improved.

3.2.3 CLOCK

Although problems with the digital clock/calendar did not impact on data collection rates, data-time information was in error on occasion during the first year. The original clock used in the system was line-frequency based and when the base weather station switched over to emergency power, the line frequency drifted away from 60 Hz such that the time was off as much as 10 minutes in 7 days. To correct this, we replaced the original clock with a quartz crystal-based clock which operated independent of line frequency.

3.2.4 DISPLAY DEVICE

The Burroughs Self-Scan display units performed extremely well, with one exception. One of the display units was apparently subjected to a significant power surge or fluctuation, which resulted in a blown power supply. After a long delay awaiting parts, it was made operational again.

3.3 Software

Unlike other aspects of the MAWS demonstration model, the software was very dynamic, with frequent changes, revisions, and upgrades made to the basic operating programs. Two changes in particular had the most profound effect on the amount of data collected at Scott. The first change had to do with changes in the communication protocol and will be discussed in the next section. The second change had to do with the number of samples taken in a specified length of time. In the original system, the RM's were programmed to sample a given sensor a fixed number of times per minute. Since the RM did not have its own time base, the SM was charged with the responsibility of telling each RM when to take an observation. At the end of a minute, when the SM communicated with each RM to retrieve the mean values, if the count was less than it should be, that minute's data for that sensor was rejected. As it turned out, there were frequent

interruptions in communication which would reduce the sample count, yet there was still a sufficient number of observations per minute to calculate a 1-minute mean. In other words, the software equated missed observations to erroneous data, which turned out to be deficient logic. This was corrected in February 1978 and the data rejection rate, based on software considerations, improved from 30 to 40 percent to about 5 percent.

A third software change which had no effect on data collection was made to correct a problem which occasionally developed with the display devices during episodes of significant weather changes. Originally, if there was a power interruption or system reset (as would often happen during severe weather, for example), the display would be wiped clean and all historic information erased from memory. This was changed so that the software no longer automatically assumed that random access memory (RAM) was corrupted just because power was interrupted. Instead, key locations in RAM were examined and if they were uncorrupted, the program proceeded as if the reset had not occurred.

3.4 Communications

In the cleansed environment of the laboratory at AFGL, where the MAWS system was checked out before going to Scott, the data transmission between the supervisor and the remote units (RM's and displays) was always error free. Even during the first 6 months at Scott, communications were carried out, with very few line transients or phone line problems degrading the data collection. By the summer of 1977 though, increased telephone central office troubles, including disconnections; severe cross talk; improper connections, such as 90-volt ring voltages entering MAWS dedicated data circuits; blown panel fuses; and line troubles, such as shorts, opens, grounds and lightning damage, combined to yield frequent data losses that were difficult to track down and correct.

In October 1977, a bank of telephone switching relays was installed on the same rack in the central office as the weather conference bridge. Although the telephone company personnel maintained that this should have had no effect on the transmission of data to and from the supervisor, it was more than coincidence that the MAWS' system ability to communicate ceased at the same time that the relay bank was put into operation. After 3 months, an alternative communication protocol was devised for MAWS which provided for the transmission of the data and suppression of the noise. In addition to this nearly continuous period of lost data, there were a number of occurrences of interrupted transmissions because of faulty phone lines, which resulted in sporadic data loss throughout the 2-year demonstration.

3.5 Power

The cause for the loss of power at individual RM sites, in most cases, proved to be easy to detect but difficult to correct in a timely manner. Power was carried to the remote sites via underground cable, which led to two problems. During the spring and fall, when extensive ground water was prevalent, the cables would become flooded and power at the remote observing sites was lost. In addition, on more than one occasion trenching crews inadvertently severed the underground cables, thereby disabling at least one site in each instance.

A lesson to be learned from this experience is to design a system like MAWS to have less dependence on continuous commercial AC power thereby preventing many of the instances of power anomalies which adversely affected MAWS operations. This could be achieved by providing uninterruptible power to all critical system components using storage batteries. By connecting them in parallel to the system components and simultaneously to the main AC-power lines so that they are continuously being charged, the battery system could take over in times of power failure. Under typical power-failure situations, this arrangement would permit most system operations to continue until power is restored. Presently, however, there are limitations to this approach because most weather sensors and some peripherals are not presently designed to operate with battery power and, of course, battery maintenance procedures would have to be developed.

3.6 Sensors

The state-of-the-art sensors used in the MAWS system performed well throughout the period. In general, individual sensors ceased to perform as a result of natural influences. For example, lightning strikes in close proximity to the sensors disabled a number of sensor components on several occasions. Sustained strong winds were extremely hard on the tower-mounted wind sets, blowing the anemometer cups or the wind vane off several times. The temperature-dewpoint sets and the forward scatter visibility meters drifted out of calibration, thereby requiring periodic maintenance. Unfortunately, in the case of individual sensor problems, errors often went undetected due to printer problems cited earlier or until an operator printed out sensor output from around the airfield for intercomparison purposes. Our long physical separation from Scott created more problems here than we had anticipated. Table 1 lists the relative performance statistics of the sensors at each observation site during the period that data were successfully archived on magnetic tape. The single biggest contributor to these figures being well short of 100 percent was the software logic problem discussed in Section 3.3. Both of the Air Weather Service (AWS) sensors interfaced to MAWS, the AN/GMQ-10 transmissometer and the AN/GMQ-13 Rotating-Beam Ceilometer, presented

Table 1. MAWS Sensor Data Collection Efficiency

Observation Site	Sensor Data Efficiency (Value in percent)					
	Dir.	Spd	Max Spd	Temp	Dewpt	Vsby
R13	71.8	69.4	59.9	72.8	52.1	71.0
MID	55.4	52.4	43.4	79.9	77.8	52.3
R31	81.0	80.2	69.1	77.7	89.5	80.4
Tower 25 m	78.2	77.8	66.2	75.2	93.2	69.6
Tower 40 m	78.4	77.6	66.3	82.1	91.5	75.9

considerable difficulty. While the GMQ-10's output was routinely archived, it was found in the post analysis that significant portions of the data were in error due to a logic error in the software. Very little cloud base height data were collected during the demonstration. The hardware and software necessary to automate the RBC were modified numerous times with only limited success. The main problem seemed to be with MAWS' inability to handle an RBC trace that had a variable signal-to-noise ratio and was heavily laden with noise spikes.

The operational configuration of RBC's at Scott AFB consists of a unit near each end of Runway 13/31. The actual display of RBC output on the standard display devices in the base weather station (BWS) is limited to signals from the RBC unit at the currently active end of the runway. In the initial MAWS hardware and software, we attempted to process and display data from both the active runway RBC being displayed in the BWS and the observation obtainable from the RBC at the "inactive" end of the runway. The operational selection process introduced electronics problems to the MAWS system which could only be solved by hardware modifications to the operational system. Since our primary purpose was simply to demonstrate the capability of integrating RBC observations into MAWS, we chose not to pursue the two-RBC solution. Thus, MAWS only processed the active runway RBC.

Aside from the fact that the AFGL sensors used in MAWS are substantially easier to maintain than standard AWS inventory instruments, both types require additional development to achieve the level of maintainability and reliability necessary for a stand-alone automated operational system. Given the rapid advances being made in solid state and microcomputer technology today, this should be attainable without too much effort. Obviously, this approach would require some major redesign of many weather sensors, but redesign which would be potentially attractive to applications beyond MAWS. Currently, most sensor output signals

present only such trivial interfacing problems for microprocessors as amplification or attenuation. In reality, microcomputer power can be applied within the sensor to calculate such things as transfer functions, scaling factors and so on. In any case, the analog interface module in a fully developed MAWS remote station could probably occupy only one or two small printed-circuit cards. In those cases where the requirements of an instrument warrant it, a separate microcomputer, possibly on a single chip and dedicated to just that instrument, is an extremely viable and economical approach using current technology.

4. DATA ANALYSIS AND INTERPRETATION

The MAWS demonstration at Scott AFB provided the opportunity to assess the impact and utility of detailed and continuously updated weather observations on an operational airfield. The focus of the subsequent discussion will be on those variables, such as visibility and wind, which are critical to safe aircraft operations. In addition, the performance of the objective RVR forecast model which routinely generated and displayed predictions ranging from 15 minutes to 3 hours will be reviewed.

4.1 Visibility Measures

MAWS calculated and presented measures of visibility in several forms: prevailing visibility, runway visual range (RVR), horizontal and vertical variability of visibility, and slant visual range (SVR). Each measure of visibility was determined from atmospheric extinction coefficient observations obtained by one or more forward scatter meters (FSM) deployed at two locations along the main runway at Scott (R13 and R31) and at the 25-m and 40-m (T25 and T40) levels of the meteorological tower placed 600 m perpendicular to R13. While an FSM was also placed near the midpoint of runway R13/R31, its performance was found to be erratic and unreliable on numerous occasions and its data have been excluded from these analyses. The visibility data collected during the 2-year period were summarized in the form of the cumulative frequency distribution (cfd) for each location. This is shown in Figure 7 along with the long-term climatological cfd for prevailing visibility based on the hourly human observations included in the Scott AFB RUSSWO (BLV). This summary reflects the fact that visibility conditions were better, on the average, during the MAWS demonstration than would be expected over the long run.

Spatial variability was examined by performing a correlation analysis on observations gathered during periods of reduced visibility. The statistics presented in Table 2 were drawn from at least 5000 minutes of paired visibility

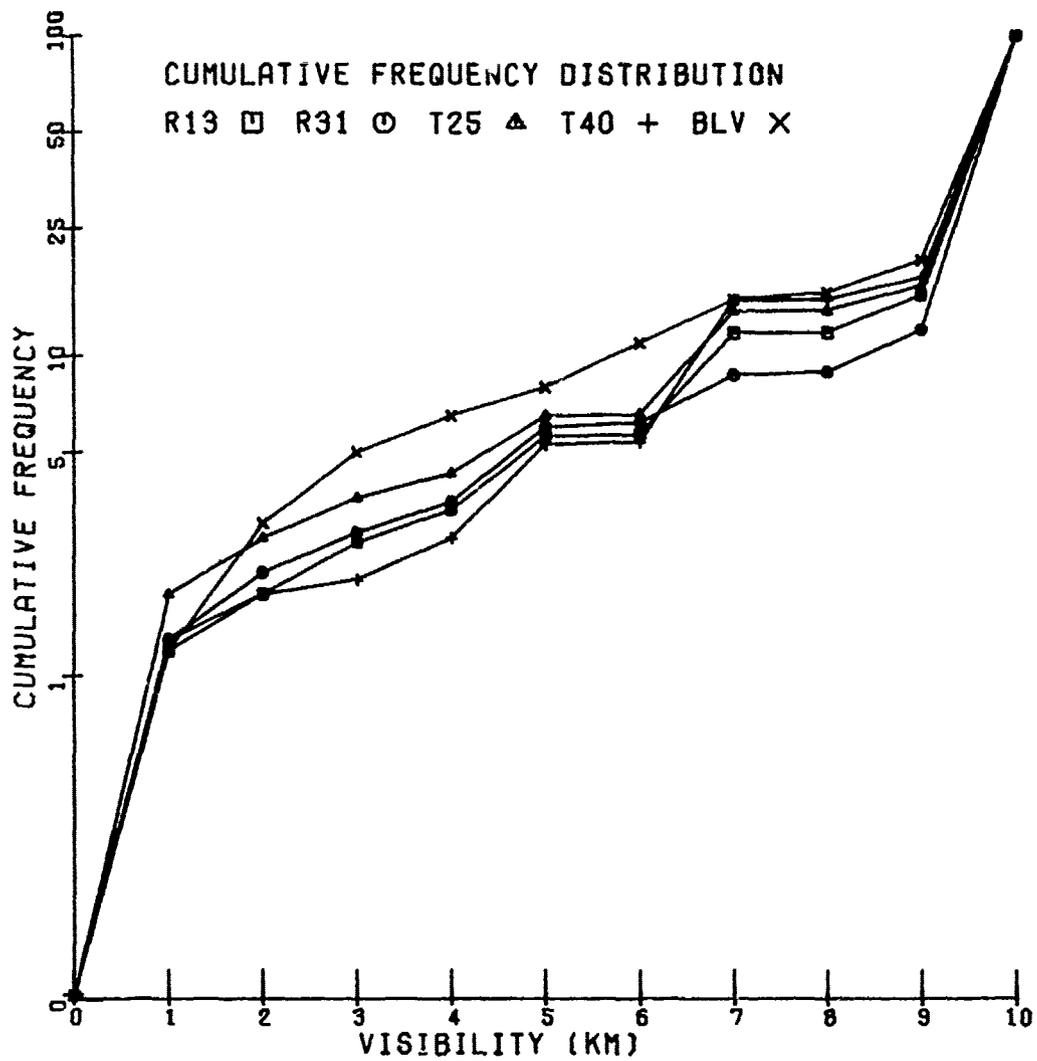


Figure 7. Cumulative Frequency Distribution of Sensor Perceived Prevailing Visibility at Each MAWS Location at Scott AFB and the Long-Term Climatology of Human Prevailing Visibility (BLV)

Table 2. Scott AFB Reduced Visibility Correlation Statistics

Sensor-Pair Locations	Correlation Coefficient (r)	Standard Error (%)
R13-R31	0.87	33
R13-T25	0.82	37
R13-T40	0.75	52
R31-T25	0.83	40
R31-T40	0.76	52
T25-40	0.95	29

observations in which the visibility was less than 4.8 km (3 mi) at both locations during the 2-year period. Radiation-fog episodes, characterized by spatially and temporally chaotic visibility patterns, occurred only rarely during the demonstration period. Therefore, these statistics are largely based on advective weather situations, with or without precipitation. They reflect patterns very similar to those obtained in the Hanscom mesonetwork experiments.⁸ We found here at Scott that vertical variability is least between the 25- and 40-m levels of the tower ($r = 0.95$) and greatest between the runway locations and the upper tower level ($r \cong 0.75$), wherein both horizontal and vertical variability factors are influencing the relationship.

It is generally recognized that observations of RVR often do not properly represent the seeing conditions a pilot encounters on his descent along the glide path through his so-called decision height. In earlier studies conducted at the Otis Weather Test Facility,^{9, 10} it has been shown that better estimates of decision height slant visual range can be obtained from point visibility measurements taken at decision height levels on meteorological towers placed to the side of runways and sufficiently far from the runways to be safe for aircraft operations. Simple

8. Chisholm, D.A., and Kruse, H. (1974) The Variability of Airfield Visibility: A Preliminary Assessment, AFCRL-TR-74-0027, AD 777 219, Env. Res. Papers No. 462, 30 pp.
9. Hering, W.S., and Geisler, E.B. (1978) Forward Scatter Meter Measurements of Slant Visual Range, AFGL-TR-78-0191, AD A064 429, Surveys in Geophysics, No. 393, 28 pp.
10. Geisler, E.B. (1979) Development and Evaluation of a Tower Slant Visual Range System, AFGL-TR-79-0209, AD A082 384, Instrumentation Paper No. 281, 42 pp.

regression relationships between FSM measurements at one or two levels of a tower combined with a measurement along the runway and glideslope slant visual range estimates for Category I (200-ft decision height) and Category II (100-ft decision height) were found to improve upon estimates based solely on RVR measurements. Typically, reductions in the percent root mean square estimation errors from 30 to 40 percent to 12 to 20 percent were realized in tests at the Otis WTF.

Based on the favorable results obtained in the Otis tests, an SVR algorithm was formulated and integrated into the MAWS demonstration in mid-1978. It combined the FSM measurements at R13 with the two tower measurements (T25 and T40) through:

$$\text{SVR} = 0.5 (\text{R13}) + 0.3 (\text{T25}) + 0.2 (\text{T40})$$

to generate the "estimated" SVR. Because the airfield at Scott AFB is active, direct measurements of SVR obviously could not be obtained in the landing zone. While the SVR algorithm was only part of the real-time system for the last several months, the basic information needed to evaluate it for the complete data collections was available and utilized. For this purpose, episodes in which the visibility was less than 4.8 km (3 mi) for periods of 1 hour or more were included in the analysis. There were 17 such episodes comprising over 12,000 minutes of data. The cumulative statistics reveal that on the average, slant visual range is less than RVR (2.1 km vs. 2.2 km) and is more variable (standard deviation of 1.4 km vs. 1.2 km). The correlation between them was found to be 0.87 while the standard error of estimation of SVR given the RVR is 68 percent, which is consistent with the results obtained in the Otis WTF tests. It had been found at Otis that the greatest difference between RVR and SVR occurred during non-precipitating periods of reduced visibility and that during periods of steady precipitation there is generally very little difference between them. Figure 8, which is a time-series plot of SVR and RVR during the latter part of a rain storm which occurred on 4 May 1977, confirms and reinforces the Otis findings. Steady rain was falling at Scott until 1300Z, after which a low-overcast stratus and fog situation persisted with slowly improving conditions. Note however that the improvement in RVR preceded improvement in SVR by up to 10 minutes. This is consistent with what a pilot would typically encounter at decision height.

Comparisons were made between sensor equivalent prevailing visibility measurements obtained by MAWS at selected locations and the hourly observations of prevailing visibility reported by the AWS observers at Scott. During the period of the MAWS demonstration, the operational observations were made at ground

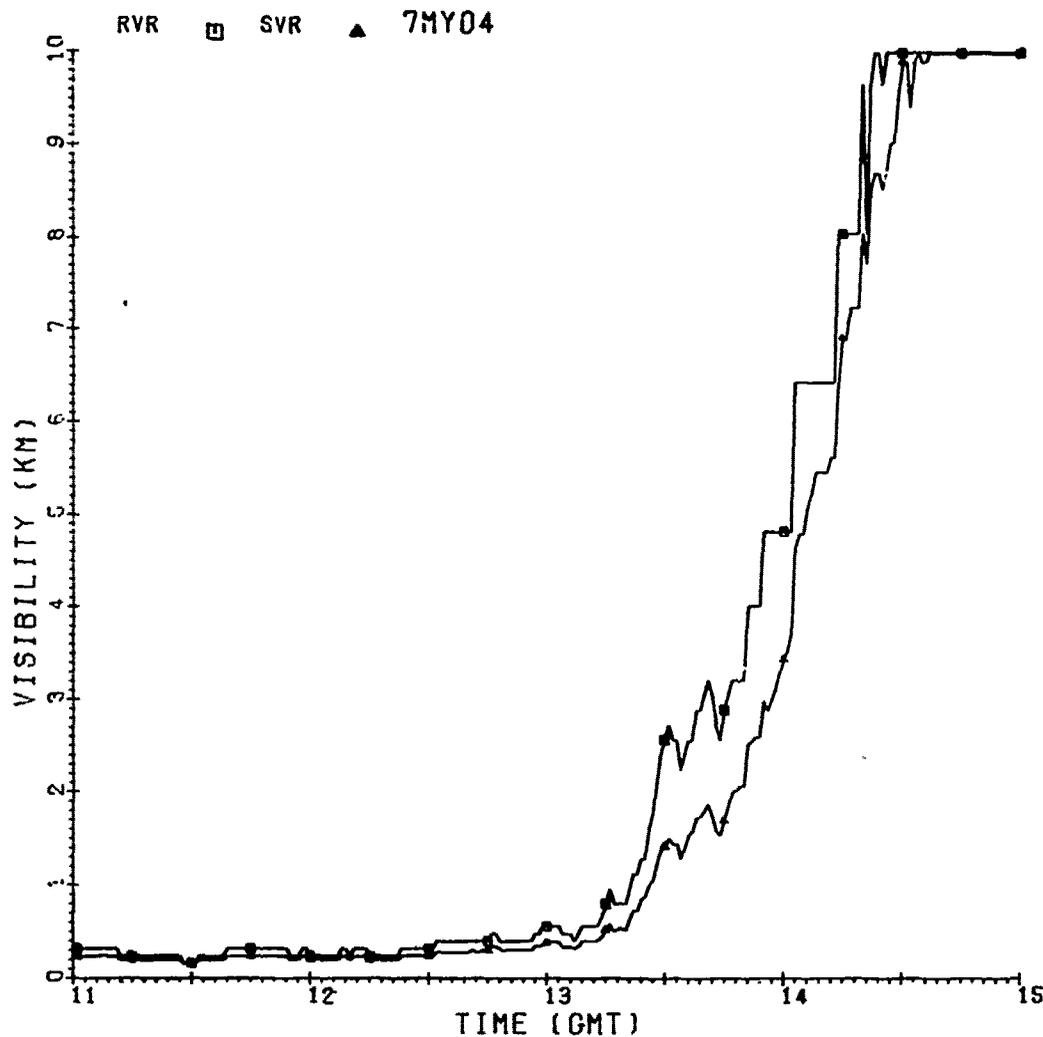


Figure 8. Time-Series Plot of SVR and RVR During Period of Rain at Scott AFB on 4 May 1977

level outside the base operations building at Scott and not from within the control tower which is located about 30 m above ground level. However, the observer often sought the assistance of personnel in the control tower when visibility conditions were marginal. Data extracted for analysis were based on AWS observer reports of visibility below 4.8 km (3 mi). Individual samples were extended to include the period before and after the sub-4.8 km range to include all observation pairs below 10 km. The operational observations were compared with the prevailing visibility measurement based on the 25-m level of the tower (see Section 2.3.3 for rationale on using 25-m level). There were 27 episodes totaling over 20,700 MAWS

observations that met the criteria. The overall statistics of the comparison are shown in Table 3. In addition, the correlation coefficient between the data sets was found to be 0.81 with a standard error of estimation of just 36 percent, statistics quite similar to those obtained in comparisons of FSM and human observations conducted by AFGL in 1971.²

Table 3. Comparison of AWS Observer and MAWS Sensor Equivalent Prevailing Visibility Observations for 27 Episodes

Statistics	Visibility Obs (km)	
	AWS	MAWS
Mean	5.36	5.38
Stand. Dev.	2.97	3.31

Some of the difference between these observations can be attributed to the fact that the human observations were obtained at ground level whereas the MAWS observations were obtained at the 25-m level of the tower. On occasion, spatial variability between base operations and the tower location could have been a factor, especially since the observer's view in that direction was partially blocked by trees and buildings. There is also an inherent tendency for human observations to lag sensor measurements by several minutes while the observer rightfully establishes that the new condition will persist sufficiently to be reported. These, plus the constraints on reportable values and criteria for specials, impact on the "variability" of human observations as compared to the MAWS observations, which have the potential of changing on a minute-by-minute basis.

The MAWS observations that were used in the comparison presented above were 1-minute mean values of prevailing visibility. The comparison was extended to assess the impact of time averaging of the MAWS data. This is summarized in Table 4, which suggests that the correlation is maximized and the standard error of estimation minimized at a 10-minute averaging time. The National Weather Service also found, in their AV-AWOS tests on prevailing visibility,¹ that a 6- to 10-minute average of sensor visibility yielded the best emulation of human observations of prevailing visibility. It must be recognized, however, that averaging over 10-minute periods may suppress minute-by-minute variations in runway visibility conditions important to aviation considerations. The following cases are presented to highlight these important situations.

Table 4. Correlation Coefficient (R) and Standard Error of Estimation (STE) Between AWS Observations and Time-Averaged Sensor Equivalent Prevailing Visibility; for Prevailing Visibility (PV) less than 10 km (1600 observations) and less than 4.8 km (240 observations)

Time Average (minutes)	PV < 10 km		PV < 4.8 km	
	R	STE(%)	R	STE(%)
15	0.790	28.4	0.856	29.8
10	0.791	28.5	0.859	29.0
8	0.790	28.6	0.855	29.6
6	0.789	28.9	0.842	31.4
4	0.787	29.1	0.829	33.1
2	0.784	29.5	0.821	33.7
1	0.783	29.6	0.822	33.6

Several cases of reduced visibility which occurred during the MAWS demonstration point up the magnitude of variation that can be expected around an airfield under certain weather regimes and the uniformity present in other events. Figure 9 shows a time-series plot of sensor equivalent and human observations of prevailing visibility at night. A weak low-pressure system was moving northeast over the south central United States and passed just south of Scott AFB at 1200Z on 12 February 1977. Steady light rain and fog in advance of the low caused Scott's prevailing visibility to decrease from 10 km at 0700Z to 1.5 km at 1000Z. As the low moved closer, the visibility continued to lower to 0.8 km by 1100Z and remained relatively constant through 1200Z. Over the period from 0700Z-1200Z the agreement between sensor equivalent and observed prevailing visibility is excellent, with a correlation coefficient of 0.96 and a percent standard error of 28 percent. Although the overall agreement is good, the downward trend reported by the observer between 0900Z-1000Z does not correspond well to the sensor equivalent prevailing visibility. However, if all the locations are considered, the lower visibility first affected R31, then R13, and finally the tower. As shown in Figure 9, a prevailing visibility derived from location R13 agrees much better than the T25 values with the observer's reports during this time. However, the horizontal variability in this advective condition was not reported by the observer. One reason for this could be, as noted earlier, that the observer's vision is blocked to the north and northwest by buildings and trees.

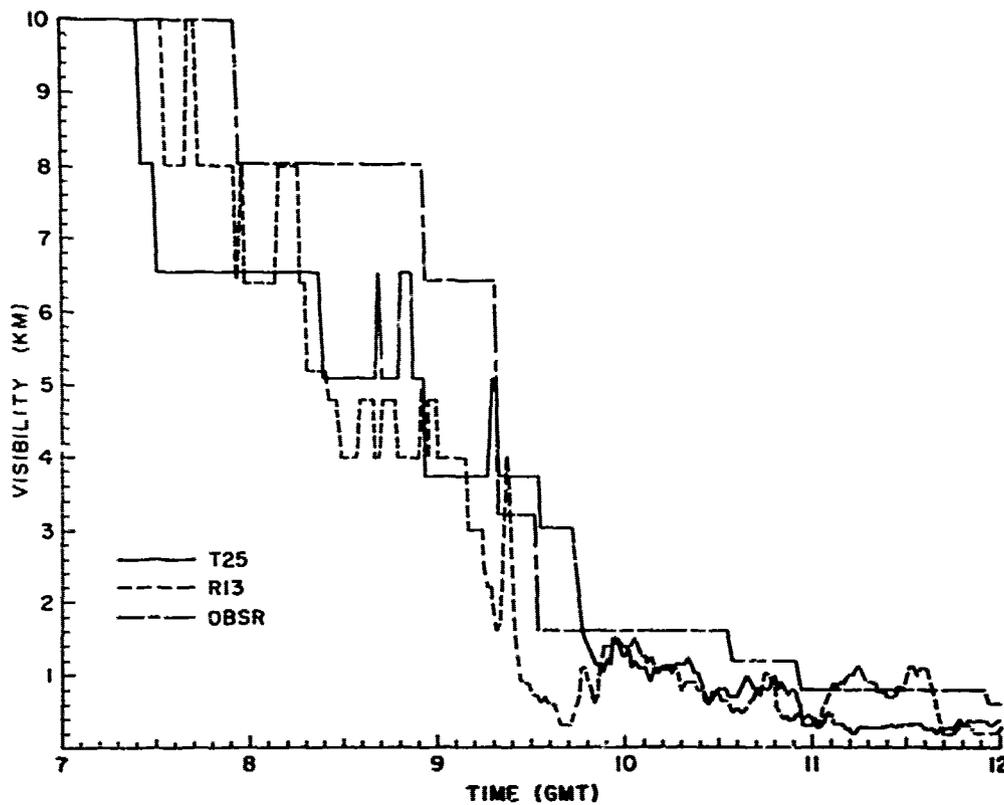


Figure 9. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 12 Feb 1977

A daytime comparison of prevailing visibility is shown in Figure 10 for 15 February 1977. An upper-level low was located over the Great Lakes with a major trough southward. In the Scott area the prevailing upper-level flow was from the northwest, with minor disturbances moving quickly through the area. Light snow was reported from 1230Z-1500Z, with periods of heavier snow showers. The comparison of MAWS prevailing visibility and that manually observed shows a very low correlation coefficient of 0.40 and a high percent standard error of 42 percent. However, the snow showers appeared to have been moving from the northwest and, as stated before, the observer's view is obstructed in that direction. Equivalent prevailing visibilities were also calculated for R13 and R31 and shown in Figure 10. From these visibilities, the snow showers appear to influence the lower tower, then R13, and finally the observer and R31. When the observer's reports are compared to R31, the correlation coefficient increased to 0.95 and the percent standard error decreased to 6 percent, a marked difference. Therefore, the observer's observation and the equivalent sensor prevailing visibility for R31,

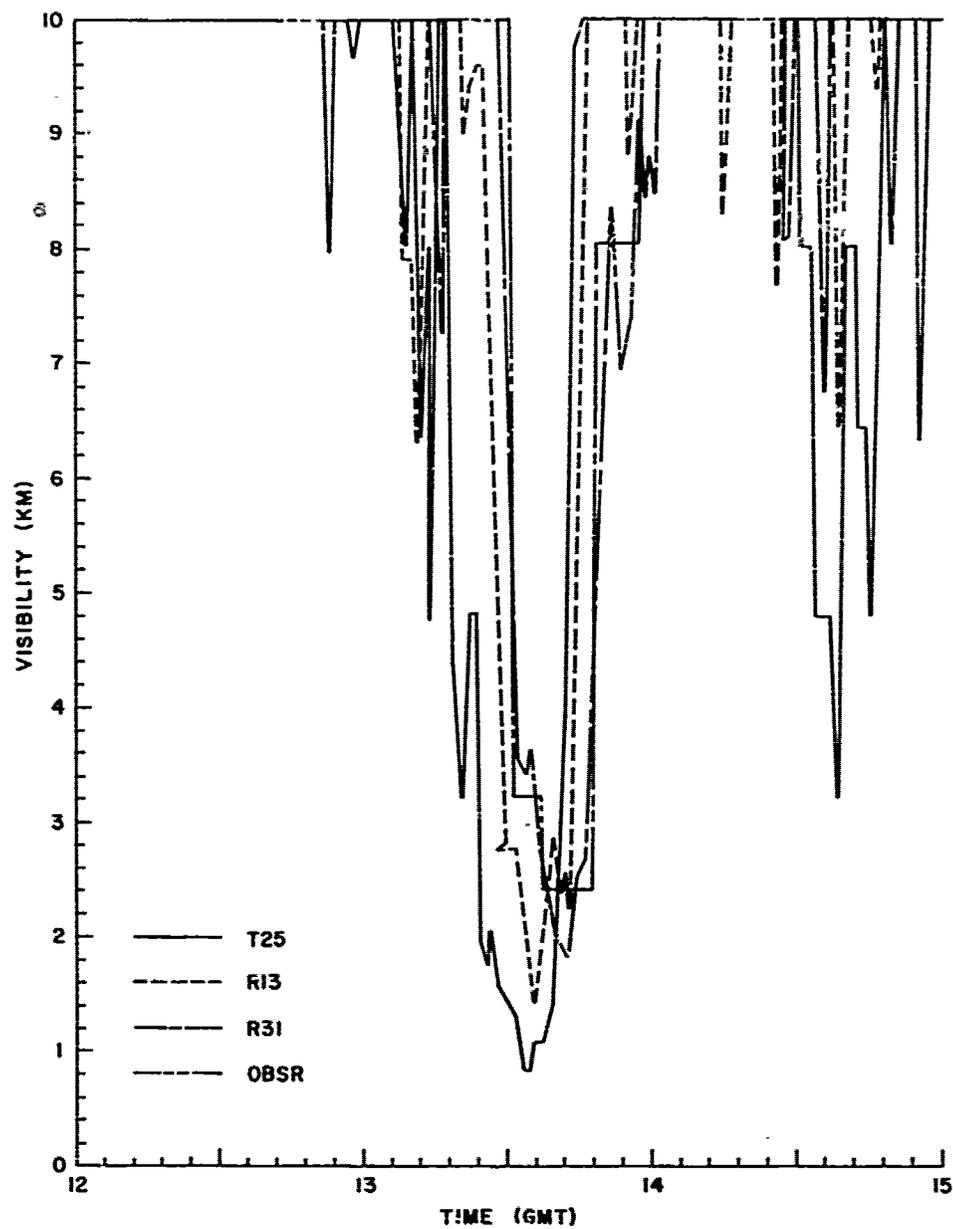


Figure 10. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 15 Feb 1977

which showed very close agreement, were representative of one section of the terminal but not of the horizontal variability of the whole terminal.

A similar situation occurred 4 days later on 19 Feb 1977. A major upper-level trough was along the eastern coast of the U.S. with strong northwest flow at 500 mb over the Midwest. A rather strong short wave moved through this flow and affected the Scott area. Light rain began at 1055Z and changed to snow at 1137Z as the temperature dropped. Blowing snow started to occur when strong northwesterly winds developed. In Figure 11 we can see the vertical as well as the horizontal variability in this situation. In the period from 1130Z-1230Z, the prevailing visibility calculated from the lower tower decreases more rapidly and to a lower visibility than that of either the observer or R31. Also during this period, the lower tower experienced the change first. From 1230Z-1330Z, the vertical variability is still evident because the lower tower continued to report lower values. However, the decrease in visibility at 1234Z at R31 and lower tower occurred during the same minute and the observer's visibility decreased 3 minutes later. From 1237Z to 1325Z, the observer carried 1.6 km visibility, but he also carried sector visibility of 1.2 km north through east at 1237Z and 1.0 km north through east at 1256Z. These sector visibilities agree well with the reports from R31 and lower tower.

The observer did an excellent job in keeping up with the changes in this situation. However, the built in lag time of 3 to 5 minutes from the time a change actually occurs to when a complete observation can be transmitted and the minute-to-minute horizontal and vertical variations that occur but are not reported are shown by MAWS.

The last example is a radiation-fog episode that occurred on the morning of 17 May 1978. A low-pressure system had passed over Scott a few days before, and a ridge of high pressure from a center over Wisconsin built in over Scott. Prior to the period shown in Figure 12, the visibility at all locations had a slow downward trend from 0500Z reaching 5 to 6 km by 0800Z. During the period from 0900-1000Z, the prevailing visibility at R13, which is representative of how R31 also behaved, showed a decrease from 5.2 km to 2.1 km, while the lower tower remained at 5.2 km. At 0955Z the observer reported 4.0 km whereas the T25 FSM reported 5.1 km, R13 reported 1.7 km and R31 reported 1.9 km. When the observer reported a decreased visibility of 2.4 km at 1005Z which agreed better with R13 and R31, the T25 continued to report 5.1 km. It was not until 1033Z that the lower tower's visibility decreased. The vertical variation in visibility in this situation, which was quite significant, was not evident from the observer's reports.

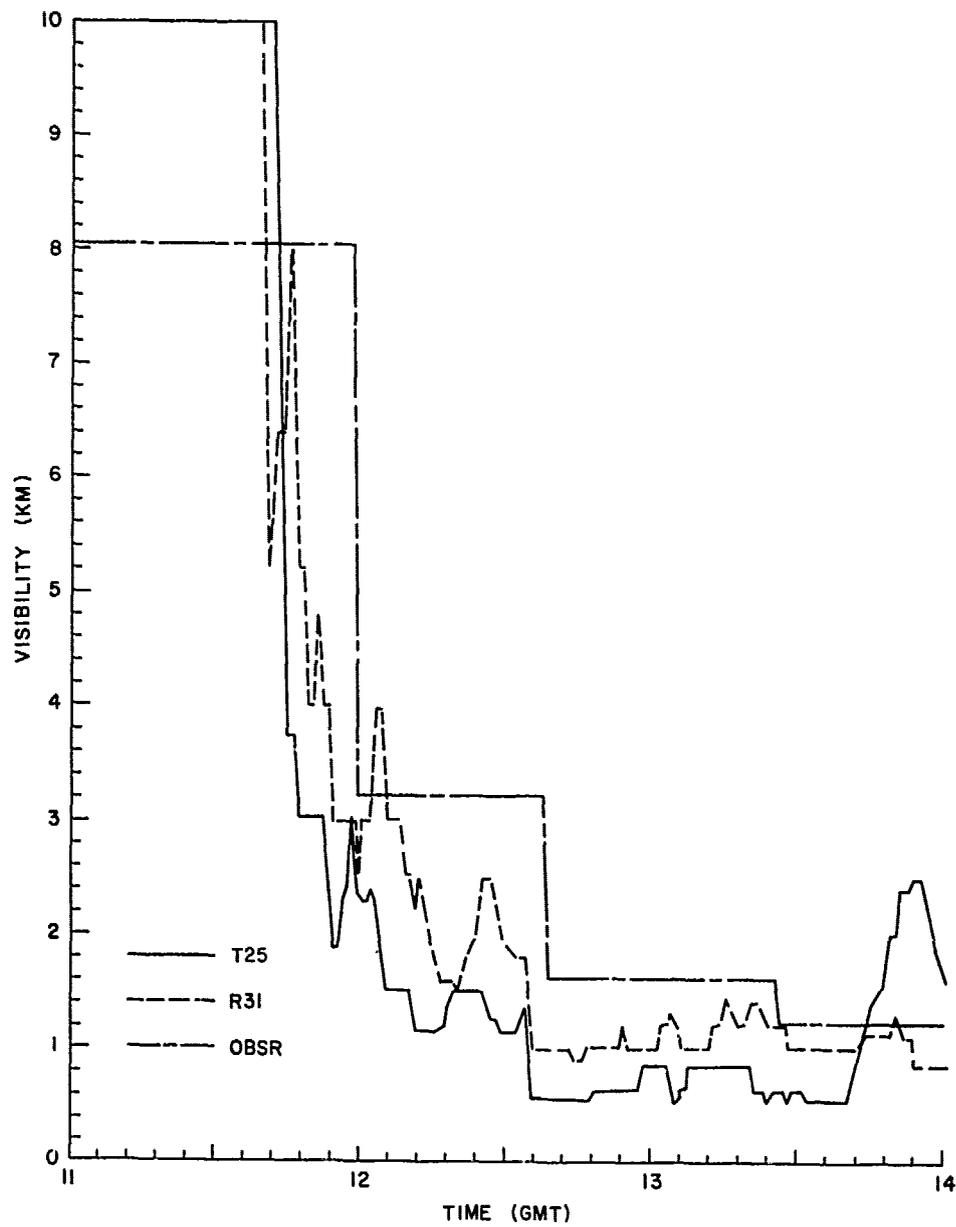


Figure 11. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 19 Feb 1977

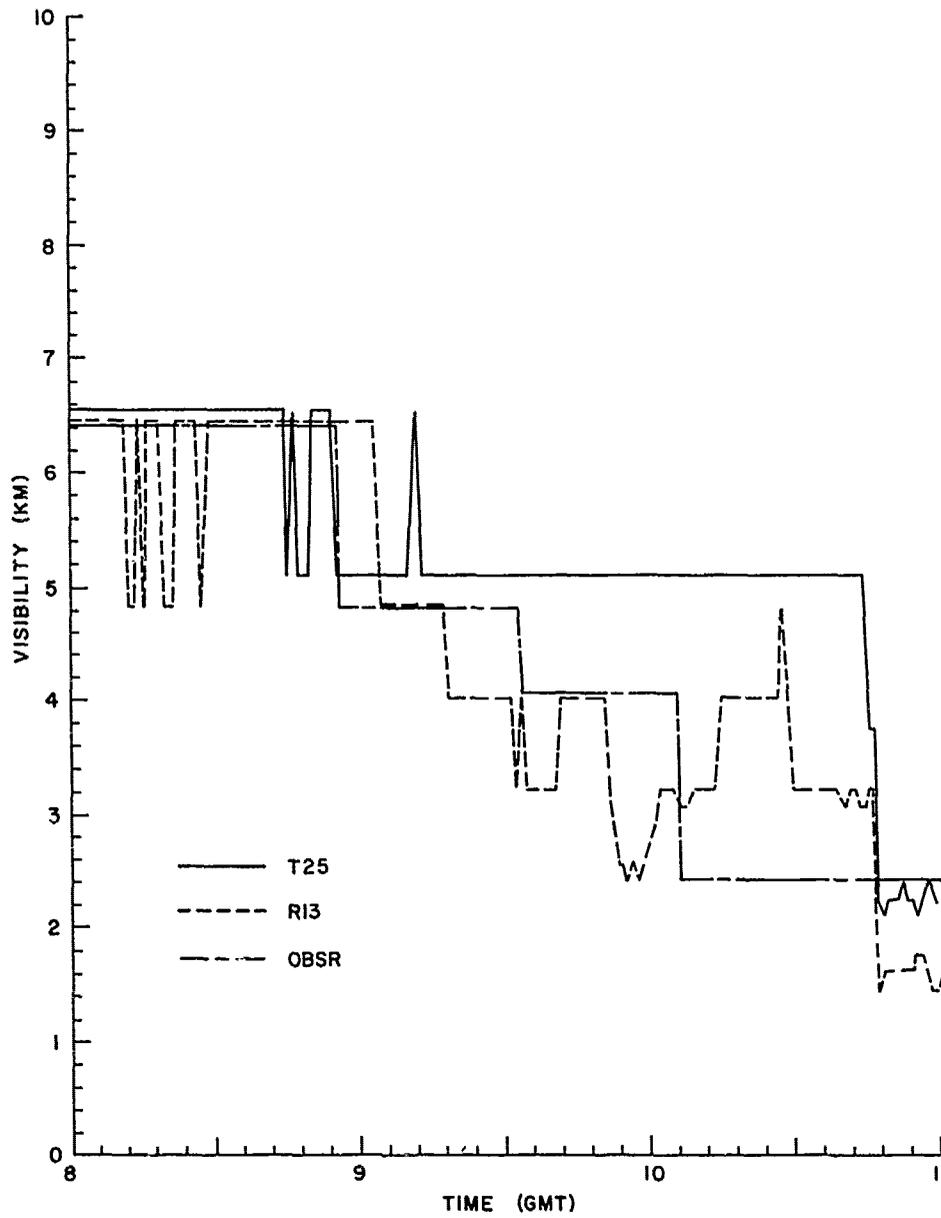


Figure 12. Time-Series Plot of Sensor Equivalent and Human Observations (OBSR) of Prevailing Visibility at Scott AFB on 17 May 1978

4.2 Wind Aspects

With the MAWS configuration of wind sets along the runway and at two levels of the tower, the system was able to provide a rather complete picture of the horizontal and vertical variability in the wind patterns over the airfield. In addition to displaying the wind vectors from the various sites, other quantities, such as crosswind component, equivalent windchill temperature, gust spread, and shears, were also calculated and displayed.

A comparison of MAWS surface winds from the active end of the runway and those routinely reported by the AWS observer was done. Although the FMH-1 requires the observer's wind direction and speed report to be a 1-minute average, quite often the average is one determined to be representative of the 5- to 10-minute period before the observation time. Therefore the average of ten 1-minute mean MAWS values was compared to the corresponding observer's report for better compatibility. In the case of maximum instantaneous wind speed, the largest value from the preceding 10 MAWS observations was compared to the observer's wind gust, if one was reported.

An excellent agreement existed between the observer's wind observations and the MAWS 10-minute mean observations. The wind direction averages were identical (192°), wind speed averages extremely close (2.9 m s^{-1} for AWS vs 3.0 m s^{-1} for MAWS) and the peak gust within 10 percent (11.1 m s^{-1} for AWS compared to 12.0 m s^{-1}). Table 5 lists comparative statistics that reflect the high correlation and low error estimates of their relationship. The degraded statistics for wind gusts were to be expected, given the different response characteristics of the MAWS wind sensor compared to the GMQ-20, the fact that MAWS sampled peak winds continuously, and finally the inherent damping effect of the mechanical strip chart recorder from which the observer extracted peak gusts. Table 6 lists the ratio of the instantaneous peak gusts to the 1-minute mean wind speed for each wind sensor for all wind data and for speeds greater than 4 m s^{-1} . These results are consistent with gust ratios determined by Tattelman,¹¹ who found that for a mean wind of 10 m s^{-1} the ratio of an instantaneous gust to a 5-minute mean wind speed was 1.48 based on airfield wind records.

Comparisons were then made between the MAWS wind observations at R13 and each of the other four locations. Table 7 lists the correlation (r), standard error of estimate (SE) and root-mean-square-differences (RMSD) for each pair, for wind speed and direction separately. As would be expected, the correlation decreases and error estimates increase as the distance between observation points increases.

11. Tattelman, P. (1975) Surface gustiness and wind speed range as a function of time interval and mean wind speed, Journal of Appl. Meteor., Vol 14, No. 7, pp 1271-1276.

Table 5. Comparative Statistics of Wind Data Reported Manually and Those Reported by MAWS. Total number of observations for wind speed and direction was 5845, and 487 for wind gust

	Wind Speed	Wind Direction	Wind Gust
Correlation	0.91	0.91	0.73
Root Mean Square Error	1.07 m s ⁻¹	50.7°	2.48 m s ⁻¹
Percent Standard Error	33%	21%	21%

Table 6. Instantaneous Gust Ratios for the Five MAWS Wind Sensors for All Mean Wind Speeds and for Mean Wind Speeds Greater than 4 m s⁻¹

Location	All Speeds	Speeds Greater than 4 m s ⁻¹
R13	1.78	1.47
MID	1.85	1.49
R31	1.96	1.47
T25	1.72	1.45
T40	1.61	1.43

Table 7. Wind Speed and Direction Statistics for MAWS Observations at Location R13 vs. the Other Four Locations (Total Observations = 110,342)

Observation Pair	Wind Speed			Wind Direction		
	r	SE(%)	RMSD(%)	r	SE(%)	RMSD(%)
R13 vs. MID	0.91	30	30	0.60	35	67
R13 vs. R31	0.90	33	33	0.67	36	35
R13 vs. T25	0.89	34	35	0.50	41	82
R13 vs. T40	0.88	38	43	0.60	37	54

This is clearly evident in the wind speed statistics but less so in the direction statistics due in part to the fact that wind direction was archived to the nearest 10° consistent with "reported" values. Although every effort was made to carefully edit and exclude erroneous data from the analysis, the poorer statistics related to the T25 wind direction observations may reflect some questionable data.

Horizontal shears were computed as the vector difference between the 1-minute mean MAWS observations at R13 and R31. Vertical wind shears were computed from the vector differences between the wind observations at R13 and upper tower (T40). The actual and cumulative frequency distribution of horizontal and vertical wind shears is shown in Table 8 as a function of speed. Wind shears in excess of 4 m s^{-1} occurred less than 1 percent of the time in the horizontal and slightly more than 2 percent in the vertical. While statistically small, the potential hazard is significant in that shears in excess of 12 m s^{-1} did occur for a total of 77 minutes in the horizontal and a total of 98 minutes in the vertical. The vast majority of significant wind shear events were transitory, lasting less than 5 minutes, and were associated with shower activity. There was, however, a situation on 19 Feb 1977 in which wind shears in excess of 10 m s^{-1} existed for a sustained period of more than 15 minutes. A sharp cold front had passed the Scott AFB runway about 1 hour before the pronounced shear conditions were established. Rapidly rising pressure (3 mb/hr), a sharp temperature drop (5°C to 2°C), strong and gusty northwest winds (330 at 9 m s^{-1} gusting to 13 m s^{-1}) and rain showers which changed to snow squalls and which reduced visibility to 1.5 km or less followed the frontal passage.

The wind conditions around the airfield were uniformly and continuously from 320° to 340° at all MAWS locations (R13, MID, R31 and both the 25- and 40-m levels of the tower) during the entire period from frontal passage until 1210Z. At that point the winds along the runway (R13, MID, and R31) started to change rather markedly. Figure 13 depicts the evolution of the 1-minute mean wind direction and speed at the three ground stations and the 40-m level of the tower from 1210Z (denoted numerically as point 1 on each depiction) through 1245Z (denoted as point 36). While the winds at tower heights were sustained from a northwesterly direction, the R13 winds proceeded to back through the SW quadrant by 1235Z before returning to the northwest quadrant by 1240Z. During the same period, the wind at the other end of the runway (R31) was veering through the northeast quadrant to a S to SW direction by 1220Z before returning, in a veering manner, to a northwest condition by 1245Z. Meanwhile, the winds near the center of the airfield (MID) were acting more chaotically, alternately veering and backing through the southwest quadrant before returning to a sustained northwesterly flow.

Since there was considerable snow squall activity at the time, disturbances having diameters 0.5 to 1.5 km which could affect the winds over the runway while not being reflected at the tower location are conceivable.

Table 8. Distribution and Cumulative Frequency Distribution (CFD) of Horizontal Wind Shear (HSR) and Vertical Wind Shear (VSR) (Comprised of 203, 567 observations of HSR and 151, 966 of VSR)

Units (m s ⁻¹)	HSR		VSR	
	Occurrences	CFD (%)	Occurrences	CFD (%)
0	49618	100.0	10881	100.0
1	100448	75.1	56146	88.6
2	36980	27.8	53284	51.6
3	11172	7.6	21976	16.6
4	3344	2.1	6510	6.4
5	1273	1.0	2012	2.1
6	347	0.35	618	0.76
7	107	0.18	193	0.35
8	64	0.13	78	0.23
9	51	0.11	61	0.18
10	39	0.08	49	0.14
11	17	0.06	31	0.10
12	30	0.05	29	0.08
13	17	0.04	28	0.06
14	14	0.03	13	0.05
15	18	0.02	12	0.04
16	14	0.01	14	0.03
17	8	*	13	0.02
18	3	*	7	0.01
19	0	*	6	*
20	2	*	2	*
21	1	*	2	*
22	0	0	0	*
23	0	0	1	*

*Less than 0.01 percent.

The importance of this fairly brief and very unusual event from an aviation point of view lies in the fact that wind speeds during the period ranged from 8 to 11 m s⁻¹, with gusts higher than 13 m s⁻¹. Thus, an aircraft landing during this time would have experienced a great deal of difficulty maintaining sufficient lift when a sustained head wind of 10 m s⁻¹ or greater above 25 m changed to a 2 to 8 m s⁻¹ tailwind condition perhaps 15 to 20 m above ground. Near

SCOTT AFB, IL
 19 FEB 1977
 1210Z - 1245Z

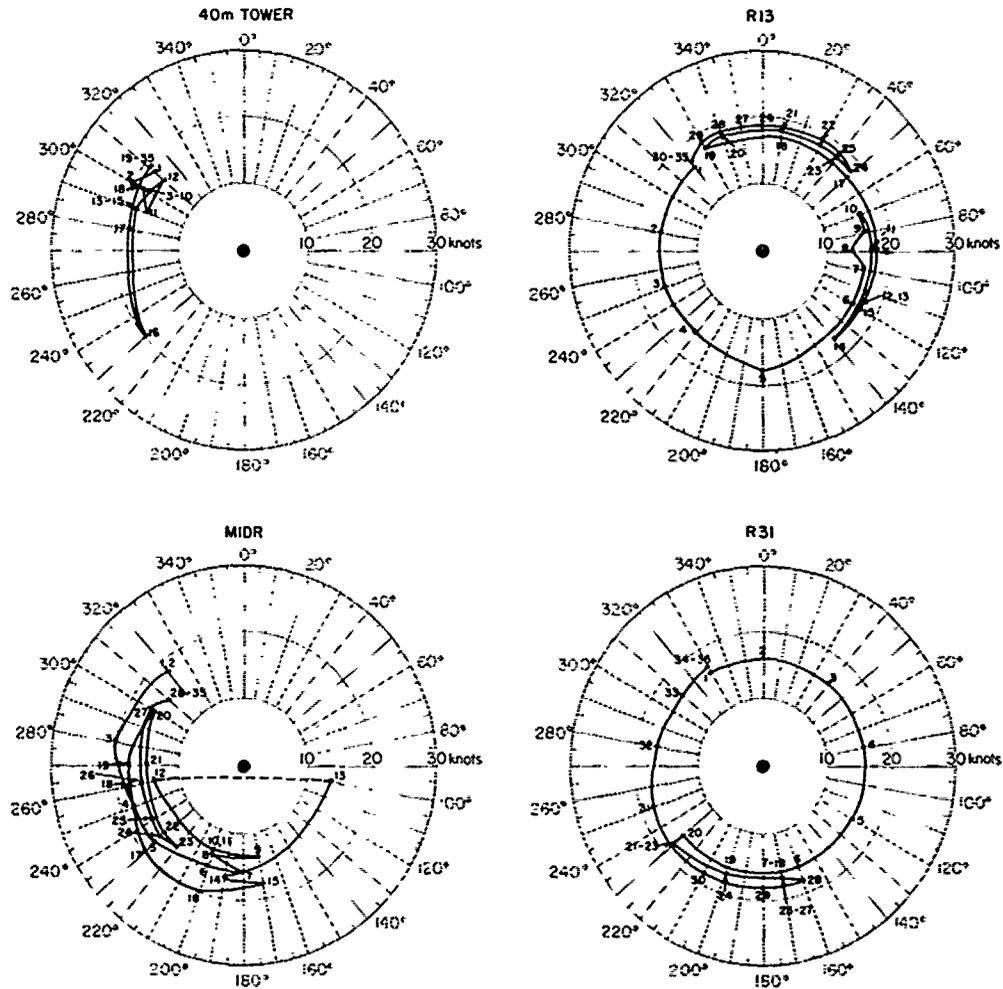


Figure 13. Variation of 1-Minute Mean Wind Direction and Speed at Three Runway Locations and the 40-m Tower at Scott AFB on 19 Feb 1977

instantaneous decreases in air speed of 12 to 18 m s^{-1} are not inconceivable in this case just at the time in the landing profile when the proper lift to drag ratio is most difficult to maintain due to landing airspeeds near stall speeds.

Three other similar episodes were also found during the 2-year period. Two of the occurrences were on 12 March 1977 when a very active cold front was approaching Scott AFB with widespread rain and embedded thunderstorms in advance of the front. Prevailing winds were from the southeast at 8 to 10 m s^{-1} , with gusts to 13 to 15 m s^{-1} . The disturbances as shown in Figures 14a and b caused vertical shears as high as 19 m s^{-1} and horizontal shears up to 17 m s^{-1} . In addition, there were prolonged periods of shears in excess of 10 m s^{-1} . The third case occurred on 24 March 1978 when a low-pressure system moved south of Scott, producing widespread rain north of the low. Again disturbances 1 to 2 km in diameter caused shears as high as 19 m s^{-1} in the vertical and 16 m s^{-1} in the horizontal. However, from Figure 14c, one can see the disturbances of 24 March 1978 were of a more transitory nature than those of 12 March 1977.

Other measures of wind variability which were part of the MAWS demonstration included crosswind component (CWC) and gust spread, which was evaluated in two forms: all data (WGS) and gust spreads when the 1-minute wind speed was greater than 4 m s^{-1} (WGS4). Wind gust spread was determined by subtracting the 1-minute wind speed from the maximum instantaneous wind speed in the past 5 minutes. Crosswind component was determined from the 1-minute mean wind vector relative to runway R13/31. Table 9 lists the relative and cumulative frequency distributions of CWC, WGS, and WGS4 based on 368,320 observations, 319,759 observations and 85,867 observations respectively. Comparing these results for the met-watch thresholds established for Scott, one finds almost 3500 observations (about 1 percent) equalled or exceeded the lowest threshold (8 m s^{-1}) for CWC while only 42 and none exceeded the thresholds of 13 m s^{-1} and 18 m s^{-1} respectively. The gust-spread thresholds were established to be consistent with the requirements for helicopter operations near the ground and were found to be exceeded only rarely (just over 400 minutes for the lowest threshold out of over 300,000 observations).

The other met-watch variable displayed at Scott was the equivalent windchill temperature, which had three threshold values (-7°C , -18°C and -29°C) recommended by personnel in Base Civil Engineering. Table 10 lists the relative and cumulative frequency distributions of windchill temperature for the times it was at or below an equivalent freezing value. There was a substantial period of time (over 21,000 minutes) during which the first threshold was exceeded with lesser amounts (3150 observations and 901) for the second and third more severe thresholds.

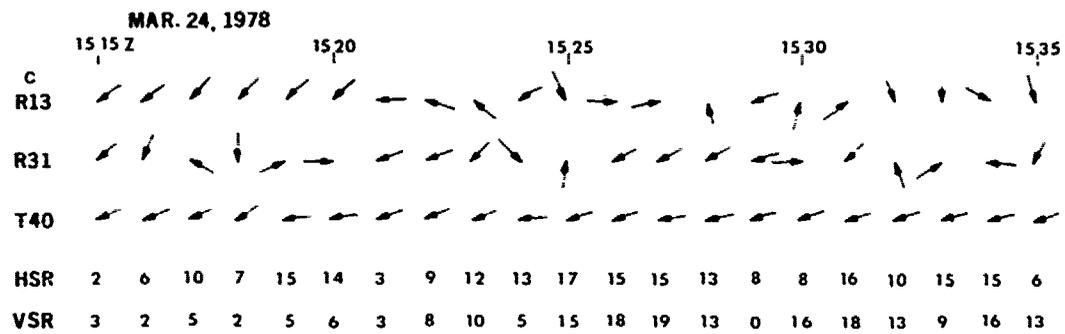
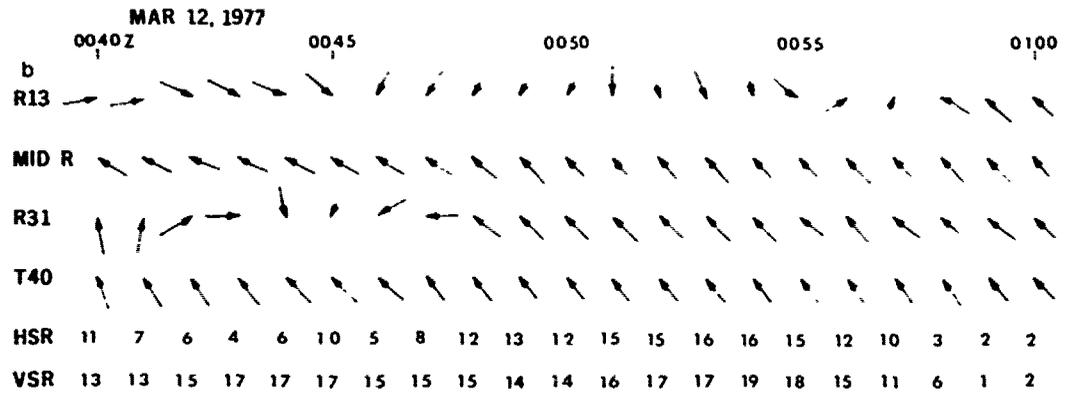
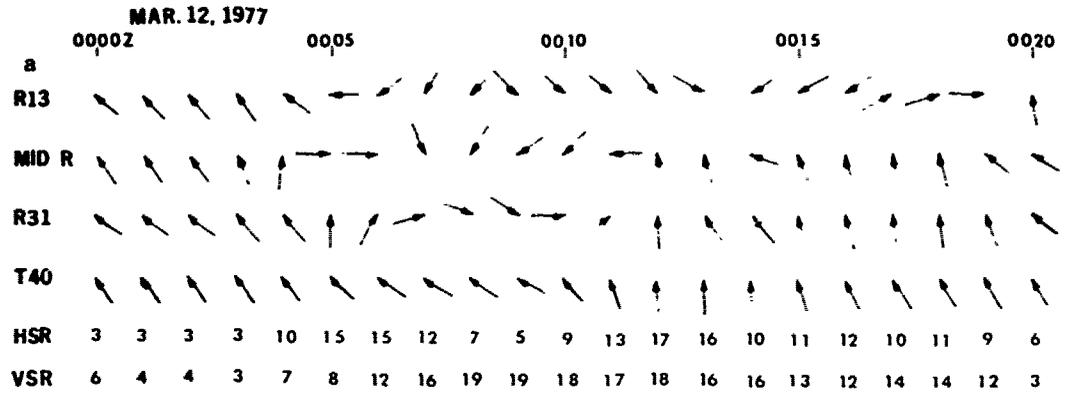


Figure 14. Three Episodes of Horizontal and Vertical Wind Shear at Scott AFB on 12 Mar 1977 and 24 Mar 1978

Table 9. Relative (RFD) and Cumulative Frequency (CFD) Distributions of Cross Wind Component (CWC), Wind Gust Spread (WGS), and Wing Gust Spread When the Mean Speed is Greater Than 4 m s^{-1} (WGS4)

Units m s^{-1}	CWC		WGS		WGS4	
	RFD	CFD (%)	RFD	CFD (%)	RFD	CFD (%)
0	90194	100.0	19719	100.0	2355	100.0
1	114811	75.5	140904	93.8	16605	97.3
2	68338	44.3	99318	49.8	27826	77.9
3	46340	25.8	37786	18.7	22049	45.5
4	22547	13.2	14078	6.9	10320	19.8
5	12879	7.1	4977	2.5	4084	7.8
6	6325	3.6	1833	0.93	1591	3.1
7	3395	1.9	654	0.33	608	1.2
8	2422	0.95	255	0.15	238	0.50
9	622	0.29	119	0.07	110	0.22
10	275	0.12	52	0.03	40	0.09
11	88	0.05	25	0.02	17	0.05
12	42	0.02	20	0.01	17	0.03
13	23	0.01	6	*	5	0.01
14	9	*	0	*	0	*
15	6	*	2	*	2	*
16	4	*	0	0	0	0

Table 10. Relative (RFD) and Cumulative Frequency (CFD) Distributions of Equivalent Windchill Temperature (Total no. of observations = 367,482)

Units $^{\circ}\text{C}$	RFD	CFD (%)	Units $^{\circ}\text{C}$	RFD	CFD (%)
-38	4	*	-18	359	0.86
-37	21	0.01	-17	484	0.99
-36	47	0.02	-16	870	1.23
-35	66	0.04	-15	599	1.39
-34	131	0.07	-14	990	1.66
-33	25	0.08	-13	1089	1.96
-32	122	0.11	-12	1407	2.34
-31	187	0.16	-11	2039	2.89
-30	137	0.20	-10	2051	3.45
-29	161	0.25	-9	1932	3.98
-28	151	0.29	-8	2851	4.75
-27	119	0.32	-7	3583	5.73
-26	108	0.35	-6	3701	6.73
-25	216	0.41	-5	4101	7.85
-24	174	0.45	-4	5978	9.48
-23	104	0.48	-3	3031	10.30
-22	215	0.54	-2	5419	11.78
-21	252	0.61	-1	5839	13.37
-20	178	0.66	0	6814	15.22
-19	373	0.76			

4.3 Temperature/Dewpoint

A comparison of the data from the three temperature/dewpoint sets along the runway confirms the obvious fact that a second site is only necessary for the purpose of providing an immediate backup capability in case of failure in the primary system. Differences that were noted in real time and in the post analysis can be attributed to the fact that a single calibration relationship was used within MAWS to convert voltage output to temperature units while variations of up to 40 millivolts from sensor to sensor can exist after calibration by the manufacturer.

Vertical temperature differences, even in the lowest 40 m of the atmosphere, can be substantial under certain stability conditions. This is reflected in Table 11, which shows the relative and cumulative frequency distribution accumulated during the 2-year period. In fact most of these extreme data (-7°C or less) occurred during the late evening of 1 Feb 1977 and early morning of 2 Feb 1977. Early on 28 Jan 1977 a front passed Scott AFB and a large high-pressure area dominated the Midwest for the next 4 days. During the late afternoon of 1 Feb 1977 warm-air advection returned at the upper levels. After sunset, with clear skies and calm winds, the surface temperature dropped rapidly while the temperature at T40 remained constant in a weak southerly wind. Temperature differences between R13 and T40 of 4 to 6°C occurred between 02/0000Z and 02/0230Z. From 02/0230-02/0800Z, this difference increased to 8 to 10°C . As the radiation inversion deepened the difference decreased to 4 to 8°C from 02/0800Z-02/1230Z. After

Table 11. Vertical Temperature Difference Relative (RFD) and Cumulative Frequency (CFD) Distribution Between R13-T25, R13-T40 and T25-T40 (Total no. of observations 272, 718)

Units $^{\circ}\text{C}$	R13-T25		R13-T40		T25-T40	
	RFD	CFD(%)	RFD	CFD(%)	RFD	CFD(%)
-10	2	*	9	*	0	0
-9	6	*	78	0.03	0	0
-8	19	0.01	175	0.10	0	0
-7	160	0.07	1061	0.49	0	0
-6	984	0.43	2927	1.56	0	0
-5	4088	1.93	6083	3.79	3	*
-4	7684	4.75	9300	7.20	24	0.01
-3	13090	9.55	13992	12.33	462	0.18
-2	23307	18.09	21420	20.18	3856	1.59
-1	53905	37.86	45913	37.02	29999	12.59
0	108473	77.63	97199	72.66	205845	88.07
1	53288	97.17	59991	94.66	32254	99.90
2	7474	99.91	13851	99.74	267	99.99
3	213	99.99	698	99.99	1	100.0
4	5	100.0	2	100.0	2	100.0

sunrise, solar heating and warm-air advection quickly broke the inversion and by 1500Z the temperature differences had vanished.

4.4 Cloud Base Height

As discussed before, very little cloud base height data were collected during the test period due to variable signal-to-noise ratios and noise spike problems. However during one period, 3-4 May 1977, a sufficient amount of MAWS data was collected to make a comparison. Figure 15 shows the sensor equivalent cloud base height (CBH), as determined by MAWS, versus the manually observed values. Clearly, the two observing techniques track each other extremely well. It should be noted that during low-ceiling situations, the observer relied almost exclusively on the CRT display of the same RBC output that the automated technique analyzed. Therefore, the automatic technique, if working properly, should correspond very closely to the observer's reports.

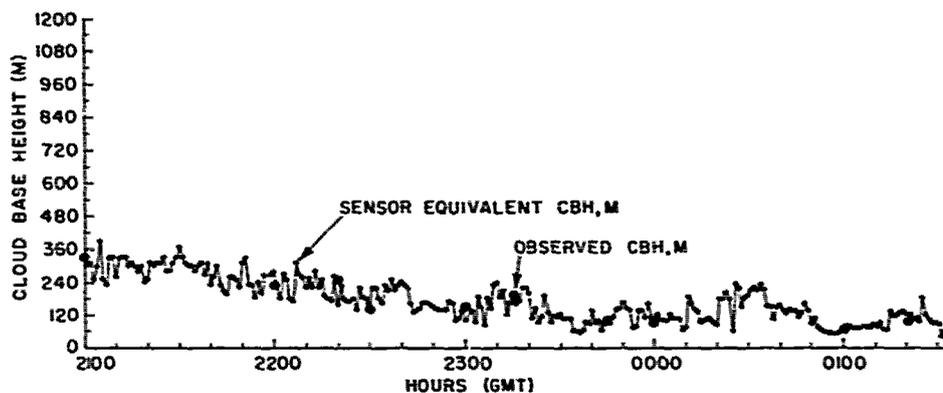


Figure 15. Time-Series Plot of Sensor Equivalent and Observed Cloud Base Height (CBH) at Scott AFE on 3-4 May 1977

4.5 RVR Forecast Model

Automated predictions of runway visual range (RVR) routinely generated and displayed by MAWS were based on a simple Markov model. Specifically, it is a special class of the Markov chain called the Ornstein-Uhlenbeck process. This model had been used extensively in earlier mesoscale visibility prediction studies. It provided valuable forecast guidance in the subjective Hanscom mesonet network experiments,¹² and was used as a control forecast technique against which more

12. Hering, W.S., Muench, A.S., and Brown, H.A. (1972) Mesoscale forecasting experiments, BAMS, 53 (No. 12), pp 1180-1183.

complex objective prediction procedures were evaluated in studies dealing with radiation fog,¹³ advective situations,¹⁴ and slant visual range.¹⁰

In the Ornstein-Uhlenbeck stochastic process, the value R_t of the continuous normalized variate at time t is related to its initial value R_0 as follows:

$$R_t = R_0 \rho_0^t + [1 - (\rho_0^t)^2]^{1/2} p$$

where

ρ_0 = 1-hour autocorrelation coefficient

t = forecast time interval (hours)

p = normalized probability

Seasonal values of ρ_0 determined during the AFGL mesonet network experiment are utilized. For the period November to March $\rho_0 = 0.96$ and from April to October $\rho_0 = 0.93$.

R_0 is determined in the following way:

$$R_0 = k \ln (RVR_0) + l$$

where

$\ln (RVR_0)$ = runway visual range (extinction coefficient) at time t_0 in logarithmic form

k, l = function of time before or after sunrise (Δt_s) through

$$k = a \Delta t_s + b$$

$$l = c \Delta t_s + d$$

where

a, b, c, d = constants and coefficients

Δt_s = hours away from sunrise.

The constants and coefficients (a, b, c and d) relate to the unconditional cumulative frequency distribution of prevailing visibility as a function of time-of-day and

13. Tahnk, W. R. (1975) Objective Prediction of Fine Scale Variations in Radiation Fog Intensity, AFCRL-TR-75-0269, AD A014 774, Survey in Geophysics No. 311, 77 pp.

14. Chisholm, D. A. (1976) Objective Prediction of Mesoscale Variations of Sensor Equivalent Visibility During Advective Situations, AFGL-TR-76-0132, AD A030 332, Envir. Res. Papers, No. 569, 31 pp.

season. For the MAWS demonstration model, these were determined from the Scott AFB RUSSWO which included 34 years of hourly observations.

A subset of the data collected by MAWS at Scott was used to evaluate the performance of the RVR Forecast Model. It consisted of those weather episodes in which the RVR was 3 mi. or less for continuous periods of 1 hour or more. There were 17 such episodes totalling 12,230 minutes. Probability forecasts were generated and evaluated separately for two RVR thresholds; 0.5 mi., which corresponds to the Category I landing minimum, and 0.25 mi., which corresponds to Category II. The results are summarized using the Brier p-score and reliability graphs.

Table 12 lists the p-scores obtained for both thresholds for the forecast intervals considered in the MAWS demonstration, namely 15, 30, 60 and 180 minutes. Figures 16 and 17 depict the agreement between the probability of below-limit visibility as predicted by the RVR model and the corresponding frequency of occurrence for two of the forecast intervals (30 and 60 min) and the two visibility thresholds. Because there were not other forecast techniques or results to compare the model output with, one must judge its performance solely from these results. The relatively small p-scores are attributable, in part, to the fact that restricted visibility episodes that occurred at Scott during the MAWS demonstration period were not characterized by frequent excursions above the below the respective thresholds. Rather, the visibility would, more typically, remain on one side or the other of a threshold for an extended period time. This is contrary to the typical pattern found with dense radiation fogs and coastal advection fogs wherein oscillations through the 0.25 and 0.5 mi. thresholds are frequently obtained.^{8, 12, 13} The degradation of p-score with increasing forecast length was expected and is consistent with prior studies. The reliability graphs reflect a systematic bias of the model to underestimate the RVR probability. The initial formulation of the Hanscom mesonet network model,¹¹ which also was based on the climatology of hourly prevailing visibility, exhibited a similar characteristic.

Table 12. Brier P-Score Results - RVR Forecast Model

Forecast Length (min)	P-Score	
	Cat II	Cat I
15	0.010	0.0023
30	0.012	0.0024
60	0.016	0.0025
180	0.024	0.0169

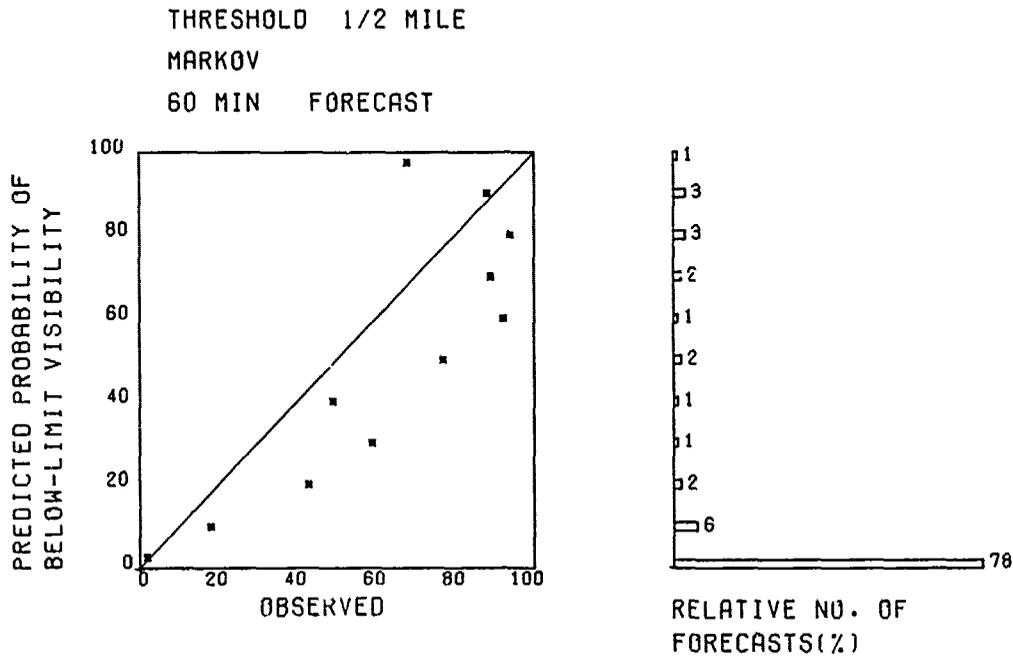


Figure 16. Probability of Visibility Less Than 1/2 Mile Predicted by RVR Forecast Model vs. the Corresponding Relative Frequency of Occurrence (60-Min. Forecast)

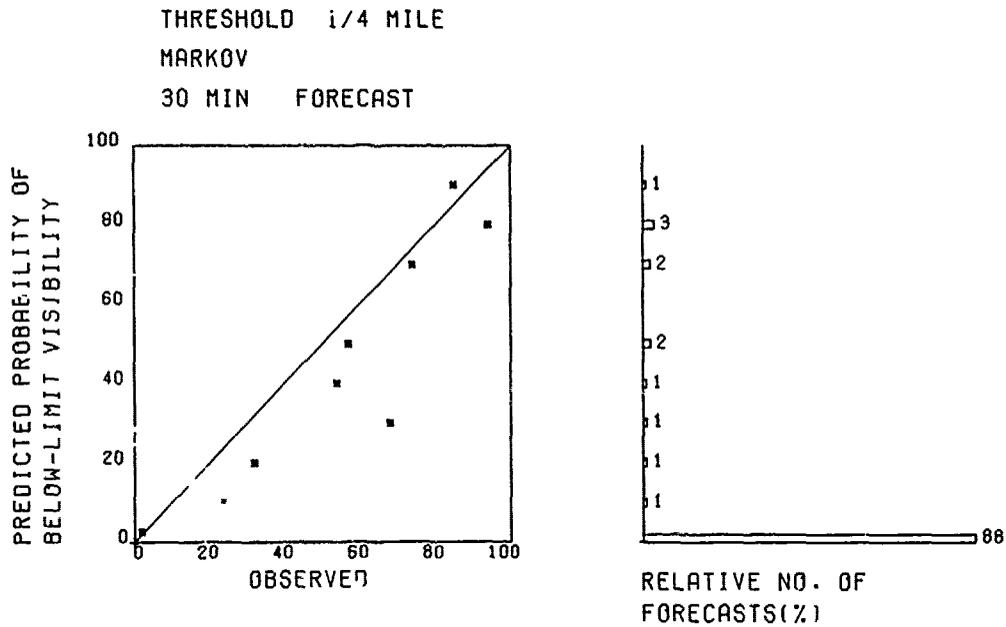


Figure 17. Probability of Visibility Less Than 1/4 Mile Predicted by RVR Forecast Model vs. the Corresponding Relative Frequency of Occurrence (30-Min. Forecast)

After 2 years of minute-by-minute observations had been accumulated at Hanscom, adjustments were made to the constants and coefficients, which reduced the bias of the mesonet model. Similar adjustments could be made to the Scott model, or for any other location, after sufficient data are gathered and analyzed.

5. SYSTEM ASSESSMENT

Scott Air Force Base was selected for the MAWS demonstration to get a day-in and day-out assessment of it by a wide cross-section of Air Weather Service (AWS) personnel. Through their knowledge of and experience with weather support requirements and existing capabilities they would provide valuable insights into MAWS' strengths and weaknesses. Feedback was achieved primarily through two mechanisms. During the course of the demonstration, a continuing dialogue was maintained between AFGL project personnel and the Headquarters, Air Weather Service staff (primarily Aerospace Sciences). Through this mechanism, many of the modifications to MAWS that evolved during the course of the demonstration were initially identified. An overall assessment of the system was obtained after the demonstration ended through the use of a MAWS Assessment Form which was distributed to Headquarters, AWS, 7th Weather Wing and Headquarters, Military Airlift Command (MAC) personnel. Appendix A includes a copy of the MAWS Assessment Form and responses obtained from specific offices. In subsequent paragraphs, the major points raised by this assessment process are discussed.

Observations - Elements Reported The objective of providing total automation in the weather observation function was only partially fulfilled by MAWS. The lack of continuous and reliable cloud base height measurements and present weather determination were the most obvious deficiencies. While primary emphasis should be on aviation elements, some installations may require "special" observations, such as refractive index profiles.

Observations-Sensors Used There was general agreement that the sensor used to obtain an observation is only important to the extent that it provides an accurate and representative weather observation. Some expressed concern regarding the need for periodic preventative and/or corrective maintenance with state-of-the-art sensors and other aspects of logistic support. Particular attention must be paid to procuring adequate interface testing and documentation when acquisition of replacement sensors and/or systems is pursued.

Observations-Frequency of Reports MAWS' routine updating of all observations every minute was deemed to be "more than adequate" during routine weather conditions. The software could be structured to routinely update observations internally every minute but only display new data on a regular interval (for example,

hourly). In addition, updating during rapidly changing and/or marginal weather, or upon user request would be desirable for some respondents. Others felt continuous updating and display was desirable particularly in aiding the forecaster's diagnosis of trends in preparing terminal forecast and flight briefings.

Observations-Trend Data The amount of trend data provided by MAWS (5, 10, 15 and 30 min ago observations) was generally considered to be excessive under normal weather conditions. Its greatest utility is during rapid weather change wherein it can be a valuable forecaster aid. Here again, a capability which permits display, on demand or during inclement weather, would be desirable. Observations 15, 30, 45 and 60 min ago were preferred to 5 to 30 min, although it was recognized this could impact the system's data storage capacity.

Observations-No. and Location of Sites The principal comment here is that requirements will vary from base to base. Therefore, flexibility in operational system design through a modular concept such as MAWS is needed.

Observation-Tower The potential as partial solution for slant visual range and low-level wind shear problems was demonstrated although it did not provide the full capability required. While it may be cost-effective to include tower-mounted sensors at a few Air Force locations, in general it may be impractical. Potential use of towers to aid in refractive index and anomalous propagation calculations was cited by one respondent as an application not demonstrated by MAWS.

Observations-Other Comments Loss of data from one or more sensors on occasion points up the need for a manual backup capability. The failure to achieve satisfactory solution to rotating-beam ceilometer automation that would function for long periods of time was deemed the most serious shortfall. One respondent discussed the need for greater attention to system reliability, maintainability, etc. before embarking on an operational program.

Forecasts-Elements MAWS demonstrated that an automated capability is feasible. However, complete requirement would include cloud base height, wind speed and direction, refractive index, etc. New types of forecasts may be required for electro-optical weapon support.

Forecasts-Output Format It was generally agreed that probability format is preferred, although there is a need to educate "users" on their meaning, method of development, and utility, especially if they are fed directly to an operator. Each variable and/or customer may have its own set of thresholds, which could present problems if they are not compatible at a given installation.

Forecasts-Forecast Length The very short range intervals were deemed excessive and the system should be extended to be more commensurate with Base Weather Station (BWS) responsibilities. For example, AWS does not need both 15- and 30-min forecasts; either would suffice. Also the need to have flexible design in order to satisfy individual base requirements was stated.

Forecasts—Other Comments Algorithms will be required for each element in the AWDS era. Local storage of algorithms and their required data bases must be available in the AWDS minicomputer. The quality of the objective forecast procedures must be documented/demonstrated as part of AWDS forecaster training/acceptance phase.

Met Watch Data—Variables Treated Met watch was acknowledged to be excellent information to have available to forecaster, controller, pilot, etc. Flexibility in the system to permit definition of variables and their threshold(s) at each installation is desirable. AWS should consider having a standard "menu" to choose from, which includes more variables than provided for in MAWS demonstration. Some variables (for example, windchill) should only be displayed "in season"; otherwise the display should be suppressed.

Met Watch Data—Thresholds Thresholds used in the Scott demonstration were appropriate for it. However, provision must be made in system design to allow for local criteria setting and possibly for dynamic capability which will allow, through manual intervention, for changing requirements for special missions.

Met Watch Data—Operational Factors A mechanism for alerting forecaster, controller, etc. to the onset of a critical condition must be a part of the system. Depending on the location of the display, this should be an audible alarm, flashing light or both. The recurring problem of the display page "rotating" away from Met Watch information during critical periods must be overcome to insure minimal need for user intervention. The format of data on the Met Watch page is generally satisfactory. However, if we go to additional variables we may need to include a second page.

Display Device—Location The Burroughs alpha-numeric display device was the component of the MAWS demonstration through which most of the respondents had their principal contact with the system. Specifically, it was the display device located in the main hall at AWS Headquarters (shown in Figure 18) that they saw. As a remote location in the demonstration, this device had receive-only status, which meant the user-viewer had little control over the page sequence and/or display duration of an individual page. The location of the display at AWS Headquarters was chosen to maximize its visibility and accessibility for the purpose of briefing visitors and DOD personnel who would eventually participate in the validation and funding of the AWDS ROC. To that end, it proved to be very effective. There was a general consensus among respondents that an operational airfield automated weather system like MAWS should include display devices in the base weather station for use by forecaster-briefers and aircrews, in the control tower, at weather support units and at staff weather office locations.

Display Device—Page Format Principal concern was related to the limited capability of the viewer to control output sequence and format. The feature of

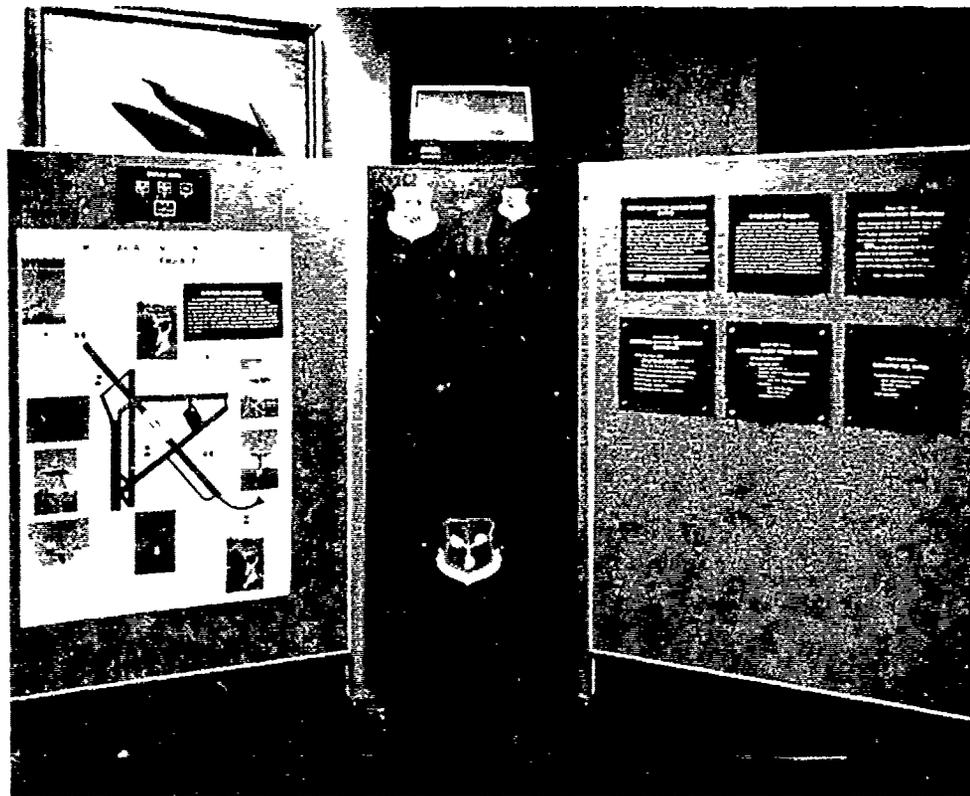


Figure 18. MAWS Demonstration Display Located at Headquarters, Air Weather Service, Scott AFB, Ill.

MAWS, wherein the four pages of display output automatically flip or rotate through a sequence, was viewed negatively by some respondents. This is a particular problem for the occasional viewer, whose familiarity with the system is limited and who must therefore spend more time studying the data and header information than the regular viewer. Consideration would need to be given therefore, in planning the format and content of display pages for the frequency of usage by the typical user. In the case of a pilot self-briefing terminal, for instance, less information need be presented on any one page and the amount of time between automatic rotation to the next page would need to be greater than in the base weather station, where the user (forecaster-briefer) would be much more familiar with format and contents due to more frequent usage. At the same time, respondent reaction would call for a manual override capability at each display terminal, which would permit holding a page for extended viewing and/or out-of-sequence advancement to a desired page.

Display Device-Readability The plain language use of words and the meteorologically accepted acronyms for variables (T, TD, VIS, etc) created little, if any, confusion among the AWS personnel who responded. The only negative comment regarding readability dealt with the large amount of data presented on one or two of the pages.

Display Device-Clarity/Wide-Angle Viewing The straight-on clarity of the Burroughs plasma self-scan panels was found to be excellent, while the view of it from wide angles (greater than 45°) was deemed unsatisfactory. In the view of one senior AWS officer, however, there "may not be a strong enough requirement to provide a wide-angle view".

Display Device-Flexibility There is a widespread view that it would be highly desirable to have greater user intervention at the display console. In addition, flexibility, which would permit the responsible base weather station forecaster to alter such items as the "met watch thresholds", would be a desirable feature to add to MAWS. It was recognized, however, that the proposed flexibility features could be cost-drivers in an operational system and they would, therefore, have to be examined in a cost vs. benefit analysis.

Display Device-Other The specific type of display device and the format/contents of its displays will vary from location to location; in an operational configuration the BWS may be best served by a CRT-type device, while space-restrictive locations like a control tower would be better served with the type of compact device utilized in the MAWS demonstration. The ability to separate the Burroughs display board from its power supply and associated microcomputer is a clear advantage when space is at a premium.

It was the widespread view of the respondents that MAWS was a highly successful research and development demonstration which provided a significant step towards the automated observation component of AWDS. The potential benefits of such a system to station personnel engaged in terminal forecasting, met-watching and pilot briefing and for automated pilot briefing were clearly recognized and acknowledged. The successes and problems of the MAWS demonstration will provide an essential data base for the design and development of the operational prototype, wherein particular emphasis will be placed on reliability, maintainability, and the other technical specialties.

6. SUMMARY AND CONCLUSIONS

The 2-year test of AFGL's Modular Automated Weather System (MAWS) at Scott AFB demonstrated that a microprocessor-based approach to modernized weather support is feasible. It provided ample evidence that the requirement for

an automated airfield observation system called for in the AWDS ROC can be satisfied. To a large extent, this can be accomplished with state-of-the-art, commercially available hardware/software which has been hardened to function in an operational environment. Specific outcomes of the demonstration included:

- a. Several operational sensors can be made suitable for automation and integration into a system like MAWS; namely
 1. AN/GMQ-10 Transmissometer with the Tasker modification kit
 2. AN/GMQ-20 Wind Sensor
 3. AN/GMQ-13 Cloud Height Indicator with a solid state amplifier modification
- b. Other operational sensors (for example, TMQ-11 Temperature-Dewpoint set, ML-512-A Barometer, ML-563/UM Barograph) either cannot be automated or would require major redesign to achieve automation.
- c. Commercially available state-of-the-art weather sensors proved themselves to be generally acceptable for operational use; namely
 1. EG&G Model 207 Forward Scatter Visibility Meter
 2. Climatronics Mark I Wind Sensor
 3. Sperry Digital Altimeter Setting Indicator
- d. The EG&G Model 110 Temperature/Dewpoint Sensor performed satisfactorily. However, it is no longer commercially available.
- e. An automated system provides valuable supplemental information (spatially and temporally) during marginal and adverse weather situations. During such weather, the need for sensors placed at multiple locations (horizontally and vertically) was documented. Aviation-critical weather elements whose spatial and temporal variability warrant multiple airfield sensors include:
 1. Visibility or RVR, at a minimum of three locations each reporting continuously; two surface measurements at runway ends and one measurement at 25 m or higher. The value of "off-the-ground" visibility information for improved guidance to a landing aircraft was strongly confirmed by MAWS.
 2. Wind speed and direction with two surface measurements and computed variables (CWC, horizontal shear) displayed continuously. The placement of a wind sensor at 25 m or higher would be recommended at locations where visibility sensors are deployed. However, while tower wind measurements would provide some additional information, they would not adequately satisfy low-altitude wind warning requirements.
- f. The modest horizontal variability of air temperature and dewpoint temperature demonstrated the need for just one surface measurement per airfield. Although not demonstrated by MAWS, the placement of temperature and dewpoint sensors at 25 m or higher could provide information useful in refractive index calculations at airfields where such information is required.

g. Key components of the MAWS microprocessor hardware proved to be quite reliable and capable of withstanding most of the vagaries of the operational environment. These included the various Intel components (CPU, PROM, RAM), power supplies, A/D converters and signal conditioners; the Burroughs flat panel display devices; and the TI dry process printer. Other elements, which performed less reliably, would have either secondary consideration in an operational environment or could be engineered more completely. These included the magnetic tape recorder, the interface with the commercial telephone system and the electrical hazards protection aspects.

h. The automatic calculation and display of met watch variables (for example, crosswind component, windchill factor) is an important feature in an automated weather system. In order to provide valuable detection and warning information to specialized user groups, this feature should incorporate an audible and/or visible alarm mechanism.

i. The basic framework of the Markov prediction model yields reliable and accurate RVR short-range forecasts at locations other than Hanscom where it was initially developed. The model's constants and coefficients can be adjusted to climatological characteristics of the airfield involved. This implies that further application of the RVR model as short-range forecast guidance would be appropriate at locations where a long term climatology exists.

j. The test and evaluation of an R&D system in an operational setting provided a unique opportunity to expose operations and staff personnel to a potential system of the future. Their constructive criticism of MAWS' performance was integral to the overall assessment of its potential. Their involvement in the demonstration should prove to be beneficial in the ultimate procurement of an AWDS capability.

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Appendix A

MAWS Assessment Form and Responses

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Overall satisfactory; was disappointed cloud base height never worked. It is a key element which must be automated for AWDS to be cost-effective.

Sensors Used (for example, Forward Scatter Meter vs Transmissometer):

Forward scatter meters appear to do the transmissometers job plus provide prevailing visibility/should continue to exploit their use.

Frequency of Reports (every minute):

Satisfactory; more frequent observations would, in general, pick up too much noise. Exception is wind speed and direction; these elements be provided continuously.

Trend Data (5, 10, 15, 30 min. earlier observations):

Probably too much; should consider backing off to 5, 15 and 30.

No. and Location of Sites:

No comment

Tower Observations:

Useful for low level wind shear and slant range visibility

Other Comments:

MAWS demonstration was highly successful. AFGL efforts greatly appreciated. Am still greatly concerned about system reliability, especially circuits from sensors to display. Outages during severe weather, heavy precipitation occurred all too frequently. Lack of cloud base height and amount major shortfall.

Forecasts

Elements Forecast (RVR and cloud base height):

Should also consider display of wind, precipitation and obstruction to vision. These may need to be manual entries.

Output Format (probability):

Logical way to go.

Forecast Length (15, 30, 60 and 180 min):

System should provide this flexibility. Each station may not require same forecast length.

Other Comments:

System must be capable of displaying the same elements currently disseminated via electrowriter. May need separate display for automated and manual output.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Also require ceiling and visibility thresholds.

Thresholds (number and values):

No comment.

Operational Factors (visual display, audible alarm, etc.):

Will require audible alarm, flashing lights/display to call attention to critical changes.

Other Comments:

Display Device

Location (AWS, Base Wx):

Satisfactory; provided high visibility to HQ personnel and visitors.

Page Format (observations, forecasts, met watch):

Satisfactory; page control still needs work. Need a page hold device. May want to consider putting current observation/forecast on page 1 and leaving that displayed as a routine. Trend observations would only be displayed on request; met watch data displayed when threshold's exceeded.

Readability:

O. K.

Clarity/Wide Angle Viewing:

Wind angle view poor to non-existent. May not be a strong enough requirement to provide a wide angle view.

Flexibility (for example, user intervention):

Very limited. Would want greater flexibility built into AWDS.

Other Comments:

Flexibility may be key item to address; however, costs may dictate otherwise.

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Believe MAWS is a significant step towards automated observing subsystem for AWDS. More emphasis is required on cloud base height and cloud coverage.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

No Comment

Frequency of Reports (every minute):

More than adequate

Trend Data (5, 10, 15, 30 min. earlier observations):

Suggest trending for 15, 30, and 45 minutes

No. and Location of Sites:

No comment

Tower Observations:

No comment

Other Comments:

Some capability to display the latest observation (with appropriate flags) when sensors are not operative should be included. There should also be some capability for manual sensor read when the display device is non-operative. This sub-element of the system should have a high reliability.

Forecasts

Elements Forecast (RVR and cloud base height):

Should also forecast wind speed/direction

Output Format (probability):

Excellent idea, but requires considerable education; particularly if output is expected to be directly used by an operator.

Forecast Length (15, 30, 60 and 150 min):

Suggest forecast lengths of 30, 60, and 120 min.—longer forecasts can be handled manually or with the AWDS processor.

Other Comments:

Reliability requirement can be significantly relaxed.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Suggest including visibility and cloud base heights; omit windchill.

Thresholds (number and values):

Should be variable with allowance for criteria setting through manual interaction.

Operational Factors (visual display, audible alarm, etc.):

Visual display with audible alarm for met watch criteria

Other Comments:

Reliability should be high

Display Device

Location (AWS, Base Wx):

No comment

Page Format (observation, forecasts, met watch):

No comment

Readability:

Updating should be stored as opposed to automatically changing displays (pages) when updating

Clarity/Wide Angle Viewing:

No comment

Flexibility (for example, user intervention):

See comment on met watch data thresholds

Other Comments:

Considering MAWS was not an operational system, the reliability was high. However, the system was primarily non-operative during periods of bad weather (based on casual observation)—this detracted significantly from "PR" aspects of the system. People don't understand that losing MAWS 30 min. out every hour is better than a manual observation once an hour.

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Add ceiling and present WX.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Not important to operator/WX man. The need is accurate observations. You tell us the best way to get them.

Frequency of Reports (every minute):

O. K.

Trend Data (5, 10, 15, 30 min. earlier observations):

In AWDS could be called up, rather than displayed all the time.

No. and Location of Sites:

Hard to fill what is gained by the mid-site. AFGL should study cost-effectiveness and make recommendation.

Tower Observations:

Nice to have but not the solution to the AWS/SVR requirement.

Other Comments:

Forecasts

Elements Forecast (RVR and cloud base height):

Add ceiling/height

Output Format (probability):

Good. Must be tailored to critical thresholds of customers. May be a problem if several thresholds are involved.

Forecast Length (15, 30, 60 and 180 min):

O. K.

Other Comments:

Need to know how good objective forecasts are. Evaluation should be a part of the AWS system.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Good, but a function of customer (operator) requirements which may vary. Should have a standard "menu" though.

Thresholds (number and values):

Same comment as above.

Operational Factors (visual display, audible alarm, etc.):

Would not rely only on visual display; need alarm or other system to get attention of WX man or user.

Other Comments:

Display Device

Location (AWS, Base Wx):

Needed only at Base WX and at key operational locations that need current WX info for example, tower, WSU, etc.

Page Format (observations, forecasts, met watch):

Distinction between the above major items good. However, not easy to understand what everything was on each page. May need 2 pages to accommodate info in obs and forecast area.

Readability:

Legibility was good, but above comment on "readability" applies.

Clarity/Wide Angle Viewing:

Not a good test bed in AWS HQ. Depends on operational setting in which device would be set up.

Flexibility (for example, user intervention):

User should be able to incorporate new thresholds as required.

Other Comments:

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Sufficient number

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Seemed satisfactory

Frequency of Reports (every minute):

More than adequate

Trend Data (5, 10, 15, 30 min. earlier observations):

Useful only when the weather rapidly deteriorates or improves.

No. and Location of Sites:

Adequate

Tower Observations:

No comment

Other Comments:

Forecasts

Elements Forecast (RVR and cloud base height):

Of limited value

Output Format (probability):

For these elements forecast, a categorical format would personally be preferred.

Forecast Length (15, 30, 60 and 180 min):

Either the 15 or the 30 minute forecast is not needed

Other Comments:

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Fine

Thresholds (number and values):

Not observed

Operational Factors (visual display, audible alarm, etc.):

Not really observed on other than visual display

Other Comments:

Display Device

Location (AWS, Base Wx):

AWS

Page Format (observations, forecasts, met watch):

Fine-Preferred separate pages

Readability:

Excellent

Clarity Wide Angle Viewing:

Limited wide angle viewing capability

Flexibility (for example, user intervention):

Not observed

Other Comments

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Cross checking with regular obs occasionally raised doubts.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Frequency of Reports (every minute):

Trend Data (5, 10, 15, 30 min. earlier observations):

No. and Location of Sites:

Tower Observations:

Other Comments:

Could be a good source of data for local 'micro' studies.

Forecasts

Elements Forecast (RVR and cloud base height):

Occasionally used.

Output Format (probability):

Not used.

Forecast Length (15, 30, 60 and 180 min):

Other Comments:

Display too rapid.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Used quite often.

Thresholds (number and values):

Operational Factors (visual display, audible alarm, etc.):

Page changes too rapidly

Other Comments:

Display Device

Location (AWS, Base Wx):

MAC/WSU in M/C Command & Control Center.

Page Format (observations, forecasts, met watch):

Most repeated comment: Pages change too rapidly; too much on a page.
Can't absorb data. Would like ability to manually hold or recall a page.

Readability:

Clarity/Wide Angle Viewing:

O. K.

Flexibility (for example, user intervention):

Other Comments:

Frequent down time and sensitivity to moisture, lighting and power fluctuation eroded credibility of system.

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Temperature /dewpoint data were faulty.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Frequency of Reports (every minute):

Very useful during periods of marginal weather.

Trend Data (5, 10, 15, 30 min. earlier observations):

Useful during periods of changing conditions.

No. and Location of Sites:

Tower Observations:

System should be designed to provide ΔT information for toxic corridor calculations when needed. (6 and 54 foot temperatures)

Other Comments:

Forecasts

Elements Forecast (RVR and cloud base height):

Elements most frequently used by operators.

Output Format (probability):

Best format for describing forecast ability of weather accurately. Real values required for ΔT forecasts.

Forecast Length (15, 30, 60 and 180 min):

15-180 min good for recovery forecast period; should develop capability to extend to 24 hours. Develop capability to forecast ΔT to 180 min in real values.

Other Comments:

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Thresholds (number and values):

Operational Factors (visual display, audible alarm, etc.):

Other Comments:

Display Device

Location (AWS, Base Wx):

AWS

Page Format (observations, forecasts, met watch):

Format good and update capability good; pages changed too rapidly.

Readability:

Excellent

Clarity/Wide Angle Viewing:

Excellent

Flexibility (for example, user intervention):

Update and page change feature allowed sequential scanning.

Other Comments:

MAWS ASSESSMENT FORM

Observations

Elements Reported:

CBH usually not available or dependable. All other items (VSBY, T, T_D, ALT, and 3 LVL Winds), RVR, RH, Pressure Change, SLP, min/max temp) Excellent.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Forward scatter meter and all other equipment independent of BWS equipment except GMQ-13 (Cloud Base Measure).

Frequency of Reports (every minute):

Since the observations were updated each minute, forecasters were able to diagnose trends which aided somewhat in preparing Forecasts and Flight Briefings.

Trend Data (5, 10, 15, 30 min. earlier observations):

Good. Aided in preparing Forecasts and Flight Briefings.

No. and Location of Sites:

3 plus tower.

Tower Observations:

Yes.

Other Comments:

Forecasts

Elements Forecast (RVR and cloud base height):

No comparisons made.

Output Format (probability):

Good.

Forecast Length (15, 30, 60 and 180 min):

Good for short range use.

Other Comments:

Not extensively used; occasionally glanced at out of curiosity.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Excellent information to have and a good aid to pilots when working. Some limitation to effective use due to maximum sensor height of 75 meters.

Thresholds (number and values):

No Comment.

Operational Factors (visual display, audible alarm, etc.):

Audible alarm not used. Visual display adequate; however, system switches from display too rapidly, requiring excessive user intervention.

Other Comments:

Not extensively used.

Display Device

Location (AWS, Base Wx):

Base Weather Station.

Page Format (observations, forecasts, met watch):

Good.

Readability:

Good; however, if not placed near the main forecaster duty station, extra effort had to be made to read the display.

Clarity/Wide Angle Viewing:

Clarity good, wide-angle viewing poor.

Flexibility (for example, user intervention):

Good, except system switched between displays too rapidly when on other than observation page.

Other Comments:

Base Weather Station Personnel Only

System Reset Procedures:

Fairly simple. Only limited instruction provided.

Operator's Instruction "Cookbook":

Once briefed on procedures and information in the "cookbook", operation of MAWS fairly simple.

Printer Output:

Good. Only one individual performed paper changing; he considered it fairly simple.

Magnetic Tape Changing:

Good. Only one individual performed tape changing; he considered it fairly simple if directions were followed.

MAWS Observations vs. Scott Observations:

MAWS observations were more sensitive and considered more accurate. However, intermittent, but at times long lasting, maintenance outages seriously affected its dependability.

Other Comments:

It is our opinion that the MAWS has excellent potential as an aid to forecasting and automatic briefing device to pilots when manual forecasting services are unavailable. This is said in anticipation that our experience with unsatisfactory maintenance of the MAWS will be corrected. We did not approach 375 AAW since 375th managers did not involve themselves with the system. Pilots expressed curiosity about the display at times but no concrete consensus of opinion was recognized.

M:WS ASSESSMENT FORM

Observations

Elements Reported:

Significant variations in temperatures were often displayed for a 30-minute profile. These variations could not be explained meteorologically.

Sensors Used (for example, Forward Scatter Meter vs Transmissometer):

Frequency of Reports (every minute):

The frequency is fine. However, page changes should be made manually only; not everytime the computer updates. The computer can automatically update the displayed page but should not flash the other pages on the screen as it updates.

Trend Data (5, 10, 15, 30 min. earlier observations):

No. and Location of Sites:

Tower Observations:

Other Comments:

It appeared the equipment had a high out-of-commission rate. The concept is good and the prototype was a good first attempt. If problems can be overcome and refractive index profiles added, the equipment will be valuable.

Forecasts

Elements Forecast (RVR and cloud base height):

Output Format (probability):

Forecast Length (15, 30, 60 and 180 min):

Other comments:

MAWS ASSESSMENT FORM

Observations

Elements Reported:

The surface weather elements reported are those most critical to aircraft operations at a terminal. Measurements on the tower provided a valuable new dimension to the observation system.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Frequency of Reports (every minute):

This is the desirable update frequency for surface weather parameters.

Trend Data (5, 10, 15, 30 min. earlier observations):

Very valuable forecast aid.

No. and Location of Sites:

The number of location of sites was optimum for the base.

Tower Observations:

Highly useful measurements in fog and wind shear situations.

Other Comments:

Lack of cloud base height data was principal deficiency. Reliability needs improvement-system outages were frequent in thunderstorm conditions and in hot weather. MAWS should serve on the basis for the automated surface observation subsystem in AWDS.

Forecasts

Elements Forecast (RVR and cloud base height):

Excellent innovative approach to short range forecasting. Should serve as baseline for development of this capability in AWDS.

Output Format (probability):

Very useful

Forecast Length (15, 30, 60 and 180 min):

Good. 15 min forecast not essential.

Other Comments:

Additional forecast elements critical to aircraft can be included to form the future AWDS capability.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Excellent benefit of automation. Windchill should be replaced in spring-summer-fall.

Thresholds (number and values):

Thresholds used at Scott were satisfactory

Operational Factors (visual display, audible alarm, etc.):

Generally satisfactory

Other Comments:

Low level wind shear a valuable addition to MAWS.

Display Device

Location (AWS, Base Wx):

Good. Served the purpose of demonstration to high level discriminations at MAC and AWS.

Page Format (observations, forecasts, met watch):

Good

Readability:

Excellent

Clarity/Wide Angle Viewing:

Good

Flexibility (for example, user intervention):

Limited capability to hold pages. No reset capability at HQ AWS display.

Other Comments:

Maximum amount of data displayed in minimum amount of space. Primary perspective in pilot briefing and forecasting.

MAWS ASSESSMENT FORM

Observations

Elements Reported:

Goal should be to automate every element of the observation, to include the remarks, required by FMH-1.

Sensors Used (for example, Forward Scatter Meter vs. Transmissometer):

Operator viewpoint: Not concerned with type of instrument; just an accurate reading.

Frequency of Reports (every minute):

Okay internal to the computer; display should change only when significant change takes place. Significant change will have to be defined for each meteorological element based on operator and meteorologist requirement.

Trend Data (5, 10, 15, 30 min. earlier observations):

Trends need to be stored internally to the computer ready for recall as needed by the operator and for algorithm use.

No. and Location of Sites:

Typical base configuration has dual instrumentation but some locations only have single instrumentation. Therefore, application software must have flexibility to accept various type configurations.

Tower Observations:

Super for the forecaster; impractical for use at bases mainly due to cost. May be justified at a few AF locations.

Other Comments:

Voice command in the control tower and base weather station would speed entry of nonautomated observation elements.

Forecasts

Elements Forecast (RVR and cloud base height):

All that are presently required for aircraft and base customer operations.

Output Format (probability):

Probabilistic and categorical

Forecast Length (15, 30, 60 and 180 min):

Base weather station now has 24 Terminal Forecast responsibility.

Other Comments:

Algorithms will be required for AWS era for each forecast element. Expect algorithms to be stored in local computer.

Met Watch Data

Variables Treated (crosswind, gust spread, wind shear, and windchill):

Space for many more variables will be required. Variables are a function of the base mission to be supported.

Thresholds (number and values):

Function of the type of weapon system supported. Selective threshold value needed, for example, 30 knot threshold for C-130. If a U-2 lands, it will have 10 knot threshold value.

Operational Factors (visual display, audible alarm, etc.):

Bells, whistles, and/or lights required. Type will depend location of equipment.

Other Comments:

Met Watch for gunnery ranges and low level bomb routes will be needed in the local AWDS.

Display Device

Good for Demo. Video display device will vary depending upon location. BWS will use CRT of some type, while the control tower may very well use an LED device.

Location (AWS, Base Wx):

Page Format (observations, Forecasts, met watch):

Readability:

Clarity/Wide Angle Viewing:

Flexibility (for example, user intervention):

Other Comments:

Work done on MAWS has been super. It is time to concentrate on AWDS operational type problems. For example, will an FM transmission system for getting observational data elements to the central processor work better than "hard-wired" transmission lines? What kind of work is AFGL doing relative to tactical weather sensors?