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16. Abstract <p>This project will ultimately serve to supplement the manner in which Texas pilots receive weather data. This will be accomplished first by inventorying the sources used by pilots to get weather data. The reliability, and convenience, of these sources will be evaluated and the unmet needs enumerated.</p> <p>The approach described above will be tailored to the needs of pilots with all levels of competency. This includes the weekend-only pilot interested in whether the local area will continue to have visual meteorological conditions (VMC) to those planning a cross-country routing in VMC, to the high time, instrument-rated pilot who will wonder about airframe icing on route or about low ceiling and visibility at the destination.</p> <p>Characterizing these sources of weather data and contrasting them to the classes and needs of Texas pilots is the essence of the first year of the project. With respect to the pilots, these "needs" will be further contrasted with the weather-related accident statistics to find if there is an indication of any relationship. However, this correlation between weather and accident statistics will primarily be a second year effort.</p> <p>The second year will be dedicated to implementing, on an experimental basis, the recommendations resulting from the first year of research. At this early date, it appears that educating the user (pilot) may be a major part of this effort. An evaluation of the convenience, safety, and cost to the state of implementation will be made. A comparison between cost and results will be completed and reported.</p>					
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DELIVERING WEATHER DATA TO TEXAS PILOTS AND OTHER USERS

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To Enhance Aviation Weather Data Available in Texas

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IMPLEMENTATION STATEMENT

The results of research documented in this report clearly demonstrates that the collection of weather data is distinct and separate from its dissemination. There are relatively few primary weather data collection sources (e.g., NWS), while there are a multitude of intermediary processing and interpretation agencies and firms (e.g., commercial outlets). In addition, several collection and dissemination sources are in transition.

The numerous sensors and overlapping dissemination systems and networks within Texas demonstrate the potential for synergistic uses of the gathered data. The transportation, construction, agriculture, and energy industries, as well as the media, all have the need for improved weather data. Coordinating weather collection and dissemination efforts between state agencies, private industry, the NWS, and the FAA will lead to improvements in the quality and timeliness of the generated data. There is also a need to standardize sensor design and construction, and to use sensors that are capable of communicating with control and monitoring equipment on a standard protocol.

Low-cost sensors are on the near horizon and will allow the Texas Department of Transportation to extend its weather data collection activities to lower volume roads in remote locations. There is also the need to explore the use of mobile sensors. One potential application of the practice is the installation of sensors on highway patrol vehicles. These sensors could effectively measure and report visibility, pavement conditions, pavement temperatures, and road friction.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation. Additionally, this report is not intended for construction, bidding, or permit purposes. George B. Dresser, Ph.D., was the Research Supervisor for the project.

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SUMMARY

A wide range of weather information sources have been identified and described, including their respective communication paths and dissemination methods. This inventory of weather data collection and dissemination systems clearly demonstrates that the collection of weather data is distinct and separate from its dissemination. There are relatively few primary weather data collection sources (e.g., the National Weather Service), while there are a multitude of intermediary processing and interpretation agencies and firms (e.g., commercial outlets). In addition, several collection and dissemination sources are in transition.

Consequently, the ability or willingness of existing dissemination and communication systems to share intermediate level weather data is somewhat limited now (largely due to organizational rather than technological limitations), and some cross-modal sharing may never be total (e.g., marine/aviation). However, changes currently in progress appear to be addressing many of these limitations. Finally, the sharing or dissemination of weather data from multiple sources can be enhanced from the user end as well. This is accomplished by making potential users aware of and familiar with sources outside their primary modal interest (i.e., user training and education).

The numerous sensors and overlapping dissemination systems and networks within Texas demonstrate the potential for synergistic uses of the gathered data. The transportation, construction, agriculture, and energy industries, as well as the media, all have the need for improved weather data. The effort to obtain improved data is often fragmented and unorganized.

Coordinating weather collection and dissemination efforts between state agencies, private industry, the National Weather Service and the Federal Aviation Administration will lead to improvements in the quality and timeliness of the generated data. There is also a need to standardize sensor design and construction, and to use sensors that are capable of communicating with control and monitoring equipment on a standard protocol.

Low-cost sensors are on the near horizon and will allow the Texas Department of Transportation to extend its weather data collection activities to lower volume roads in remote locations. There is also the need to explore the use of mobile sensors. One potential application of the practice is the installation of sensors on highway patrol vehicles. These sensors could effectively measure and report visibility, pavement conditions, pavement temperatures, and road friction.

CHAPTER 1. INTRODUCTION

This study examines the delivery of weather data to Texas pilots and other users. Researchers are evaluating the quality and timeliness of the information in terms of pilot (user) needs. The two-year project consists of two one-year phases. The first is primarily an inventory of weather collection equipment and techniques currently in use. The second phase is a demonstration of supplemental procedures suggested by the study to improve the weather data product for the user.

There are almost 50,000 pilots in Texas. However, the type and extent of their flying habits are unknown, especially their habits in collecting and using weather data to make go/no-go decisions. It is currently not known what additional weather data is needed to improve their decisions.

Texas has about one-tenth of the aviation activity of the nation. The annual accident rate nationwide is about 2000 accidents, of which about 400 are fatal. The corresponding rate for Texas is therefore about 200 accidents, of which about 40 are fatal. The Air Safety Foundation estimates that 20% of all accidents are weather related and more than 25% of all fatal accidents are weather related. Therefore, in Texas about 40 accidents per year and 10 fatal accidents per year are weather related. It is unclear whether better weather information would reduce the number of accidents.

Improvements are rapidly being made in all aspects of aviation technology, especially in avionics. Enhanced capabilities and decreasing costs characterize these developments. For example, using state-of-the-art equipment costing about half as much as a standard communication radio, a Cessna 150 pilot leaving Austin can immediately determine the course direction, distance, current ground speed, and arrival time at a destination. However, such navigational capabilities increase the potential for the pilot to fly into adverse weather inadvertently. Therefore, the ability to know, in advance, the location and extent of turbulence, icing, or restrictions to visibility is becoming more important than ever.

The need for better weather information is not limited to pilots. Contractors, surface transporters, fire fighters, forest fire guards, hazardous materials managers, fishermen, and farmers all want more detailed and more reliable weather observations and forecasts.

Fortunately, similar improvements have been made in meteorology, the science of the atmosphere. Our understanding of both the basic phenomena of the atmosphere and the application of that understanding to weather surveillance and forecasting is growing rapidly. Tedious manual observations and record keeping are being replaced by orbiting weather satellites, automated data acquisition, automated data processing, and digital computer analysis. Sometimes, these data are not available to those who need it. In other instances, the data have been made available. However, the users, including pilots, must know how to collect them, have the equipment available to collect them, and have the training required to evaluate properly and use the data to make reasonable decisions.

Every user, especially the pilot, to some extent must be a meteorologist. A briefer can provide data and assist in its interpretation, but ultimately it is the user who must make a decision based on the weather and the forecast. Once the pilot is in the air, help may be available at the other end of the radio, but it is the pilot who must complete the flight safely. Therefore, weather data is critical.

If a pilot intends to make a flight near an airport on a sunny, calm day under Visual Flight Rules (VFR) conditions, the go/no-go decision is easy to make: Go. Similarly, if the pilot is flying cross-country, carrying passengers through forecast freezing rain and severe thunderstorms the decision is just as easy to make: Do not go. However, many flights must be made after pilots determine that a reasonable decision is not so easy to reach. The objective of this research is to determine if there are measures the Texas Department of Transportation (TxDOT) can implement to help pilots make these hard decisions easier—and wiser.

This project will ultimately serve to supplement the manner in which Texas pilots receive weather data. Researchers will accomplish this by inventorying the sources pilots use to obtain weather data. The research team will evaluate the reliability, and convenience, of these sources and enumerate the unmet needs.

The research team will tailor the approach described above to the needs of pilots with all levels of competency. This includes the weekend-only pilot interested in whether the local area will continue to have visual meteorological conditions (VMC) to those planning to take a cross-country route in VMC, to the high time, instrument-rated pilot who will wonder about airframe icing en-route or about low ceiling and visibility at the destination.

Characterizing these sources of weather data and contrasting them with the classes and needs of Texas pilots is the essence of the first year of the project. With respect to the pilots, the research team will further contrast these “needs” with the weather-related accident statistics to determine if there are any relationships. However, this correlation between weather and accident statistics is primarily a second year effort.

The second year will focus on implementing, on an experimental basis, the recommendations resulting from the first year of research. At this early date, it appears that educating the user (pilot) may be a major part of this effort. The research team will evaluate the convenience, safety, and cost of implementation to the state. Additionally, they will document a comparison between cost and results.

The research team will pursue, on a demonstration basis, implementing the project’s first-phase, first-year recommendations and conclusions during the second phase, second year of the project. Based on the success of the demonstration, the team anticipates integrating the results of the project into the services that the Aviation Division provides to pilots and others.

These recommendations may take several forms including new equipment or new ways of using equipment currently in the field or new ways of using weather information now available for making go/no-go decisions. The research team will also consider developing short seminars and courses to educate the users how to interpret National Weather Service (NWS) products. In addition, they will explore the potential for supplementing the equipment that is available to state agencies and to all surface travelers for collecting weather information, such as, automated signs warning of fog ahead.

CHAPTER 2. INTERVIEWS WITH NWS, FAA, AND OTHER AGENCIES

NWS

The NWS is a branch of the National Oceanic and Atmospheric Administration (NOAA), a part of the Department of Commerce. The objectives of the NWS are to contribute to the safety, health, welfare, comfort, and convenience of the public, and to meet the needs of all segments of the national economy for general weather information. This is accomplished by providing the public with current weather information, warnings, and forecasts through a variety of media. Recently the NWS revised its mission statement to read: "To provide weather and flood warnings, public forecasts and advisories for all of the United States, its territories, adjacent waters and ocean areas, primarily for the protection of life and property. NWS data and products are provided to private meteorologists for the provision of all specialized services." The revised mission statement was developed in response to Vice-President Al Gore's National Partnership for Reinventing Government initiative.

The NWS is reorganizing to better use new and emerging technologies. Some emerging technologies include systems that capture data from automatic sensors and process this data with large digital computers. Improved satellite data, more sophisticated radar, lightning detectors, and improved communications technologies for distributing information are other advancements requiring changes in NWS operations.

The reorganization and its impact on NWS products were mentioned frequently during the research team's interviews. Organized and equipped in the late 1980's, the NWS provided excellent service, especially for observing and forecasting large-scale events occurring over several days. The ability to develop 3-to-5 day forecasts became as reliable as the 1-to-2 day forecast of the previous decade. However, meteorologists needed more and higher quality observations of the atmosphere—from more locations—to improve warnings of highly localized and sometimes lethal events such as severe thunderstorms, tornadoes, and microbursts. The installation of many remote (although most are at airports) and unmanned, continuous weather sensor sites resulted in an avalanche of data, too massive, both in quantity and in time, to process and understand, by customary modes of weather data manipulation.

A new, three dimensional software program that includes a workstation and a communications platform, called the Advanced Weather Interactive Processing System (AWIPS), was developed to process and disseminate this massive amount of weather data. The interactive program is designed to permit forecasters to quickly extract and assimilate the most meaningful information from the morass of data. Its purpose is to integrate computer guidance information from the National Meteorological Center with satellite imagery and radar coverage. It is envisioned that the AWIPS will be the centerpiece of each of the 119 Weather Forecast Offices (WFO) and 13 regional River Forecast Centers (RFC) the NWS is establishing. Figure 1 shows the location of the 10 WFOs planned for Texas. Generally, there is one WFO for each Next Generation Radar (NEXRAD) site.

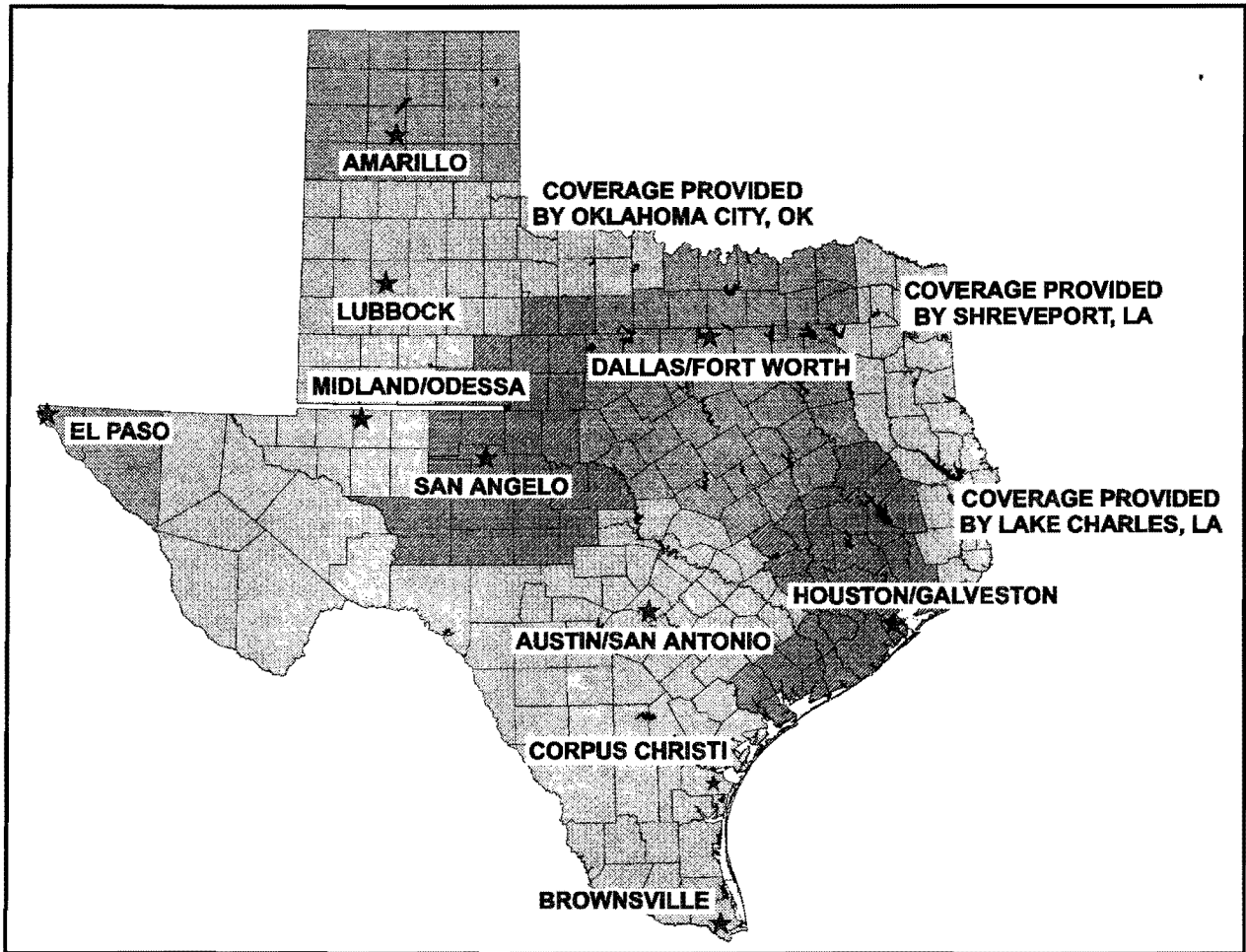


FIGURE 1. Location of the 10 WFOs in Texas Proposed by the NWS.

The one RFC in Texas, called the West Gulf River Forecast Center (WGRFC) is located in Fort Worth. Each RFC develops river forecasts, flash flood guidance, self-help procedures, and water supply forecasts for the area served. The area served by the WGRFC is shown in the map of Figure 2.

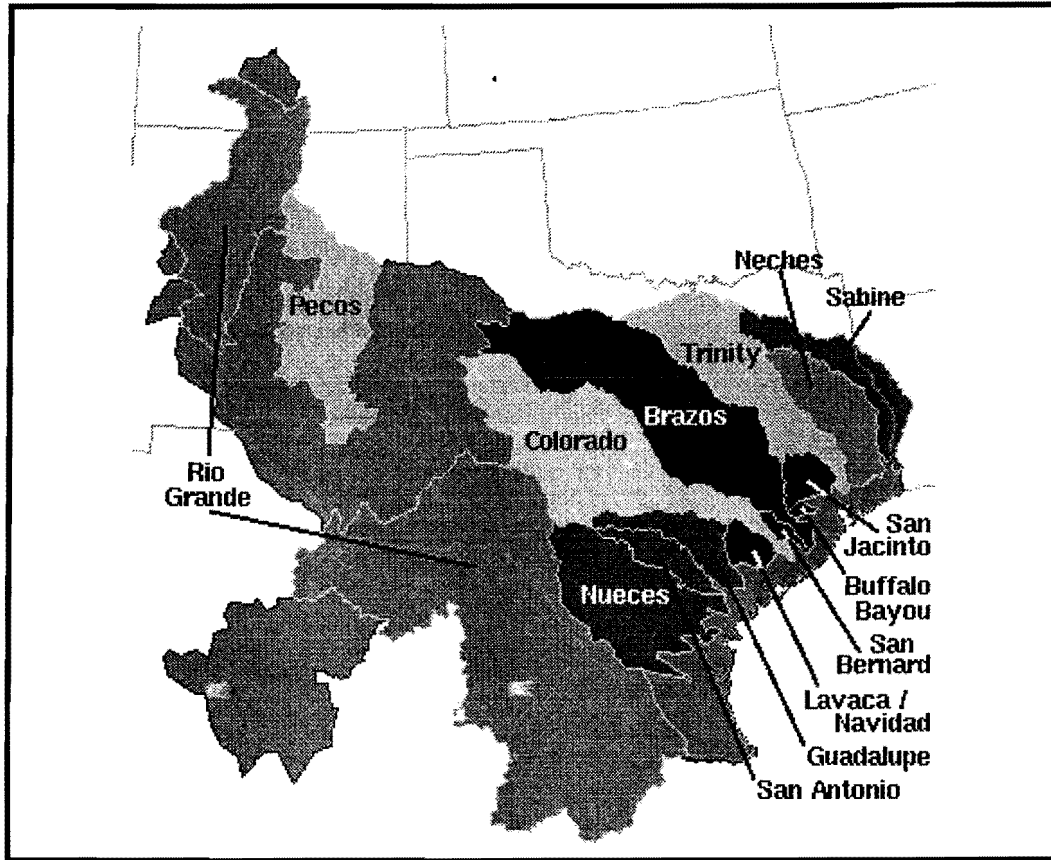


FIGURE 2. Areas Served by the WGRFC.

FEDERAL AVIATION ADMINISTRATION (FAA)

Following the crash of American Eagle Flight 4148 near Roselawn, IN, in 1995, the FAA devoted much of its energy toward generating information that will help pilots evaluate the potential for icing during a flight. Flight 4148 was in a holding pattern at 10,000 feet, when it was cleared to descend to 8,000 feet. The autopilot was flying the airplane in supercooled, large-droplet icing conditions when the airplane rolled over into a tight spiral, hitting the ground at 375 knots and killing all 68 persons aboard.

The National Transportation Safety Board (NTSB) determined that the crash resulted from large droplets hitting the leading edge of the wing then running back and freezing aft of the part of the wing protected by inflatable boots. The airplane was not designed for this weather phenomenon. Additionally, forecasters did not know how to forecast the occurrence of this icing. At the time, Hazardous In-Flight Weather Advisory Service (HIWAS) and other weather reports and forecasts did not include icing intensities or precise altitudes that would cause icing. In addition, icing forecasts were not updated quickly enough. The NTSB recommended

implementing icing “nowcasts,” with two-hour valid times and placed an increased emphasis on supercooled, large-droplet icing education in pilot training programs.

The development of more precise icing forecasts is a top priority for the FAA. For example, they now have five working groups studying the following areas: (1) icing environmental characterization; (2) ice protection and ice detection; (3) forecasting and avoidance; (4) requirements for and means of compliance in icing conditions; and (5) operational regulations and training requirements. Algorithms for forecasting altitudes and geographical areas where aircraft icing may occur are under development and testing. Some forecasters believe that the problem of overwarning, with Airman’s Meteorological Information (AIRMETS), will greatly improve with the use of satellite observations. Aviation weather forecasting has a reputation for being overcautious, to the extent that it is criticized.

Wind shear is another threat to flight safety as airplanes approach an airport. As planes descend and slow down, they become vulnerable to erratic winds. An extensive research effort was undertaken to develop equipment for identifying the presence of low-level wind shear. One result of this effort was development of the Low-Level Wind Shear Alert System (LLWAS). This simple low-tech approach compares wind speeds and directions at anemometer sites at the center of an airport with those at the periphery of an airport. Several of these systems are in use at major Texas airports. Another wind shear detection system is the Terminal Doppler Weather Radar (TDWR) that senses and reports wind directions and speeds. This radar scans the extended centerline of selected runways searching for wind shear, either on vertical or horizontal geometrical planes. Figure 3 shows the TDWR sites in Texas. (1)

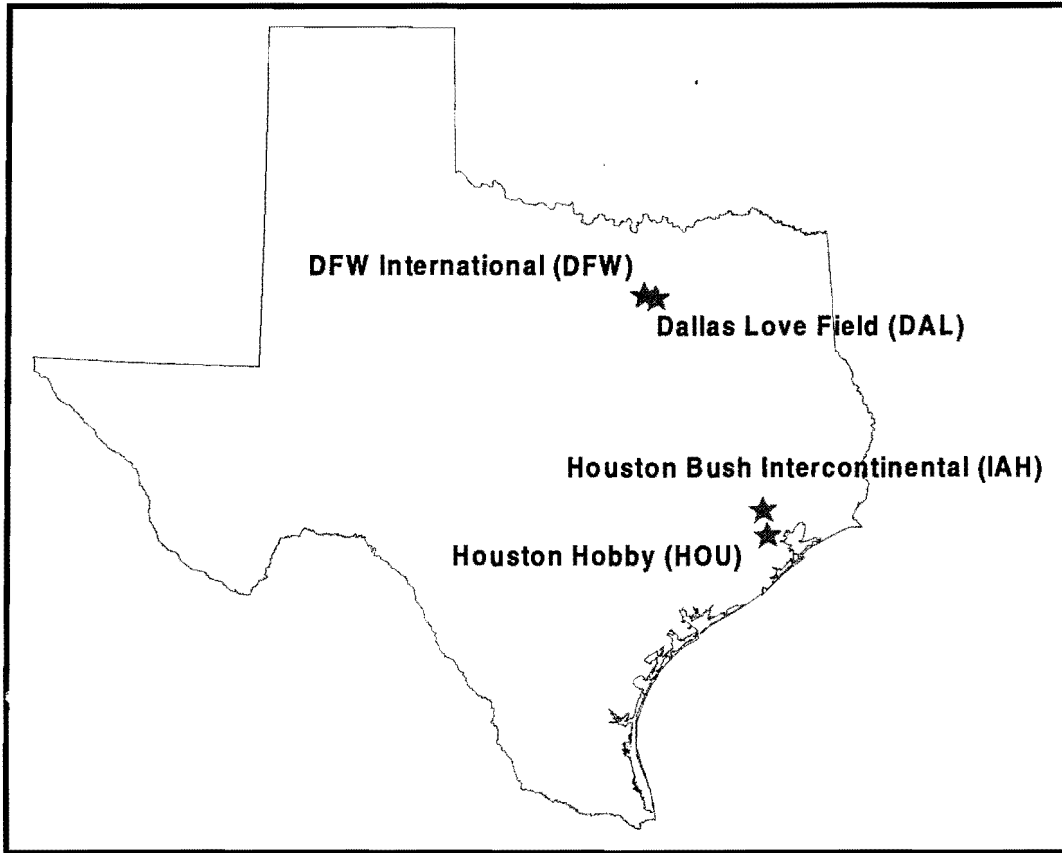


FIGURE 3. TDWR Sites in Texas.

National Airspace System

The FAA's National Airspace System Plan consists of goals for using the nation's airspace and airports more efficiently and safely. The plan's goals include: improve the safety of all flight operations, increase the system capacity, fully use the capacity resources as required to meet traffic demands in all visibility conditions, better accommodate user preferred flight trajectories and free-flight routings, and better accommodate a full range of aircraft types and avionics. Other goals of the plan include: improve the dissemination of aviation information for users including information on expected traffic congestion and delays, the status of facilities and airports, and navigation capabilities, and increase the user involvement during in-flight decision making. The goals especially emphasize the dissemination of pertinent weather observations and forecasts in simple, easy-to-understand formats to provide a knowledge base for the in-flight decision making process.

To accomplish the weather-related goals in the plan, the FAA is seeking to:

- improve the accuracy and resolution of weather observations and forecasts;

- enable users to plan for, rather than react to, operationally significant weather;
- enable users to assimilate weather information more quickly and minimize misinterpretations;
- provide tailored weather products for all users;
- increase air traffic control (ATC) efficiency by minimizing ATC operations in the presence of operationally significant weather;
- provide weather information in a timely manner; and
- provide common and consistent weather information among all users.

The FAA is currently considering a myriad of options for implementation to accomplish these goals. Following is a discussion of the FAA's current and planned weather data dissemination system.

Current System

Figure 4 shows the current system for disseminating weather data from a functional standpoint. The FAA and the NWS share primary roles and responsibilities. The NWS is responsible for basic meteorological services, including observations and forecasts, to meet the needs of the public for the protection of life and property. The FAA is responsible for aviation weather data as a specialized meteorological service that builds upon the NWS's operations. The FAA develops aviation weather data itself, or funds the NWS or the private sector to produce data.

Commercial weather information service providers have developed rapidly and can package and disseminate meteorological information to users. Users may include the FAA, NWS meteorologists working within FAA facilities, airports, airlines, and private pilots.

It is not believed that the relative roles of the FAA and NWS will change significantly during the next few years. Observations, forecasting, communications, and dissemination of information will all remain integrated. Due to its meteorological science and information base, the NWS will continue its primary role in basic meteorological and weather forecasting. Working with the NOAA, the FAA is supporting the development of techniques to automate warning and short-term aviation weather forecasts.

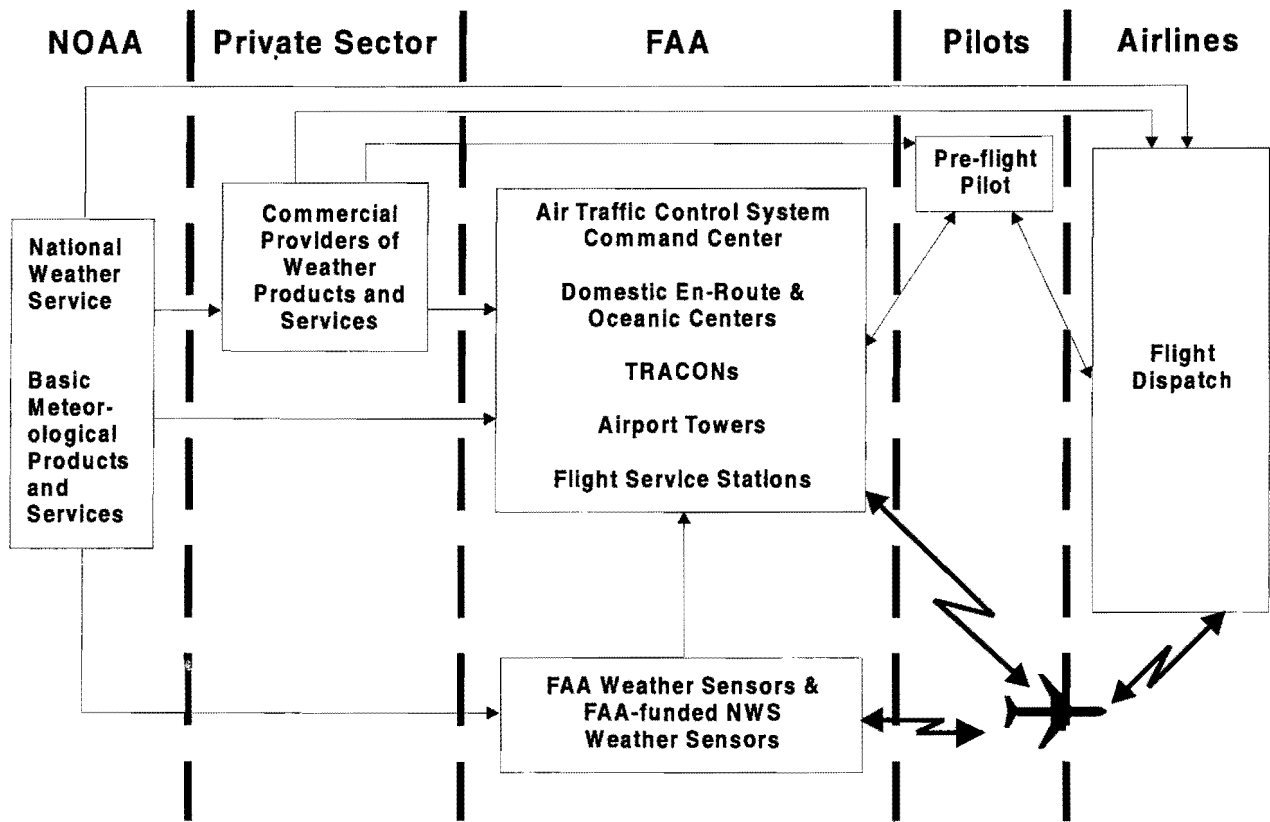


FIGURE 4. Current Aviation Weather Dissemination System.

Planned System.

Figure 5 shows the aviation weather system envisioned for the future. This system will provide more efficient operations, improved safety, greater airspace capacity, and flexible aircraft routing systems. All components are route specific and are disseminated either by voice or data link (including satellite communications). Each aircraft, depending on the equipment on board, will have access to information about weather conditions along the intended flight route. If these conditions suggest a route change, the system will suggest alternate routes commonly understood by both the pilot and the controller.

A study of Figure 5 shows a tendency for the primary source for aviation weather to shift from the FAA to the NWS and the private sector. The government will give the private sector a four-dimensional observation and forecast database so vendors may provide value-added information. This high-resolution database will specify operationally significant current and forecast aviation weather conditions with more precision, thus enhancing safety. A data link will disseminate in-flight weather information automatically directly to the cockpit. Pilots not data link equipped will still have access to the current en route flight advisory service.

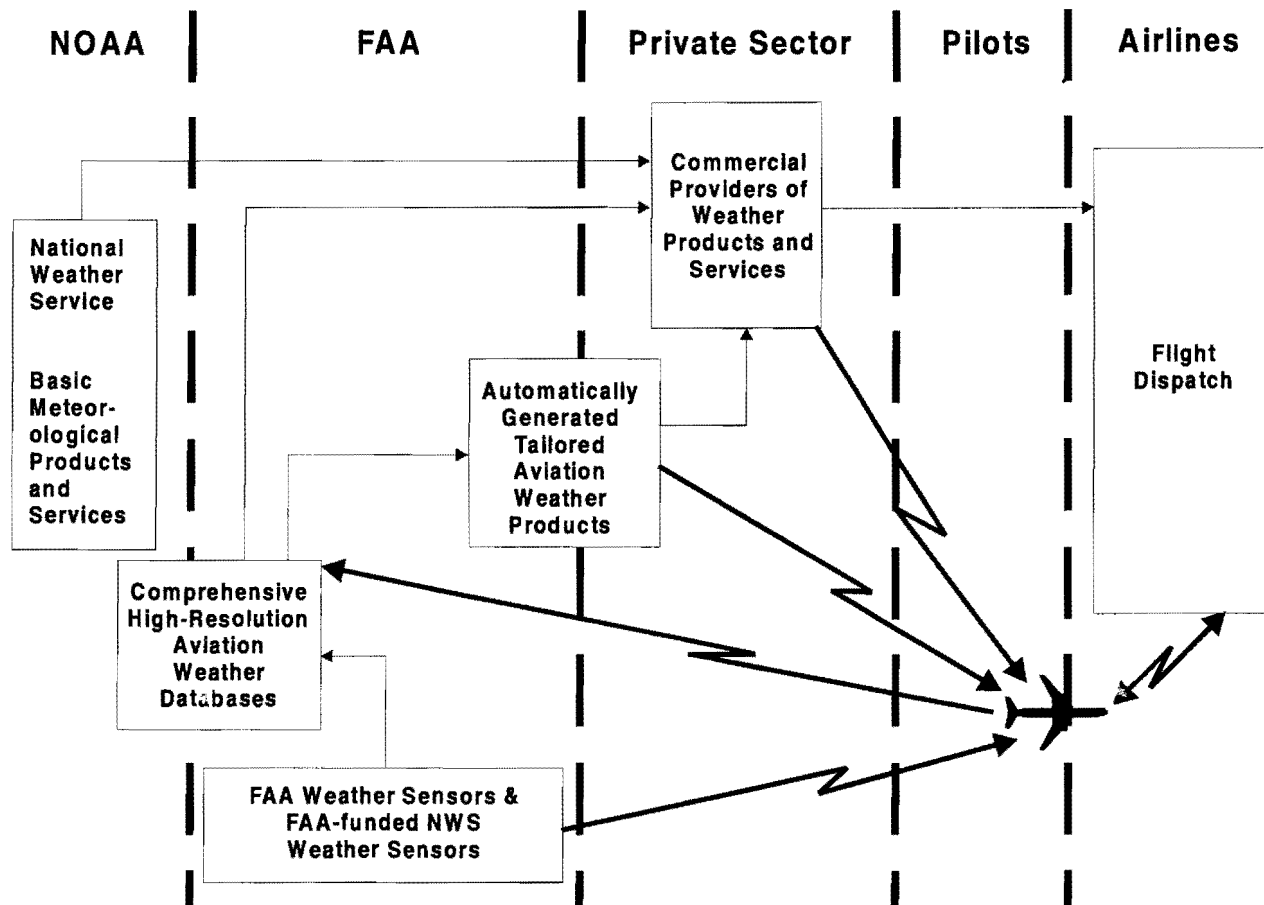


Figure 5. Future Aviation Weather Dissemination System.

AUTOMATED FLIGHT SERVICE STATIONS (AFSS)

Automated Flight Service Stations (AFSS) are the primary source of weather information available from the FAA for pre-flight planning. There are 61 stations currently in service across the nation. There are three stations in Texas: San Angelo, Fort Worth, and Montgomery County. However, the station in Albuquerque serves a small portion of far West Texas near, and including, El Paso. While briefings are available in person at each station, the most common method of accessing the weather information is via the telephone. The universal number is (800) WE-BRIEF. The user may request different briefing formats depending upon the user's needs. For most purposes, a "standard briefing" is requested, but for updates, an "abbreviated briefing" is preferred. Users needing briefings for long range planning purposes can request an "outlook briefing." Typically, the standard briefing will include:

- adverse conditions;
- VFR flight not recommended (if appropriate);
- weather synopsis;

- current weather;
- forecast weather (en-route and destination);
- forecast winds and temperatures aloft;
- alternate routes (if any);
- aeronautical information (NOTAMS);
- ATC delays; and
- request for Pilot Reports (PIREPS).

Other weather data services available from an AFSS includes the En-route Flight Advisory Service (EFAS), Transcribed Information Briefing Service (TIBS), and the HIWAS. The EFAS operates over the dedicated frequency of 122.00 megahertz (MHz) to give airborne pilots current weather information both from PIREPS from other aircraft and from sources available to the AFSS. The format prescribed for a PIREPS is shown in Figure 2. This includes a radar screen from a nearby NEXRAD. The TIBS is accessed by dialing a menu code when users first contact the AFSS. Weather condition reports along the more common routes served by the AFSS are periodically taped and played to the user making the request. HIWAS transcriptions are played over selected very high frequency omnidirectional radios (VORs) throughout the Air Route Traffic Control Center (ARTCC) geographical area. These transcriptions cover hazardous weather conditions such as turbulence, icing, Instrument Flight Rules (IFR) conditions, and high winds and will include Significant Meteorological Information (SIGMET), convective SIGMETs, AIRMETs, severe weather forecast alerts, and center weather advisories.

COMMERCIAL WEATHER SERVICE VENDORS

There is a trend toward commercial vendors playing a more predominant role in providing weather data collection and dissemination services in the future. Figure 4 shows how weather is currently presented to the pilot, while Figure 5 shows the plan for delivering weather data to pilots in the future. The figures show commercial vendors taking a more predominant role in the collection and delivery of weather data and information. A list of commercial vendors with links to their Internet home pages is located on the Internet at: <http://www.nws.noaa.gov/im/more.htm>.

TxDOT

TxDOT primarily uses road weather information systems (RWIS) to assist maintenance managers in making decisions concerning the deployment of emergency crews during inclement weather.

OTHER STATES

Several, if not most, of the State DOTs are attempting to sense and better utilize weather data. Typically, they are working with off-the-shelf weather sensors primarily designed to help maintenance personnel determine if conditions dictate immediate corrective action. Usually this involves snow or ice removal.

These RWIS consist of the actual sensors and three other identifiable components—the remote processing unit (RPU), a central processing unit (CPU), and the communications link

between the units. The RPU is located at the site of the sensors and the CPU is usually located at the district headquarters, where it collects, analyzes, and distributes the data and forecasts coming from the sensors. (Texas has about 15 RWISs in service in three districts.)

Dissemination is accomplished through a variety of methods. For example, a universal 800 number, widely publicized and widely known by all travelers within the state, could be made available allowing automobile and truck drivers to obtain important weather information. (This is the method used by the FAA's Flight Service Station.) Typically, such information would include data about the following weather safety considerations:

- ice on bridge;
- ice on road;
- high water on road;
- fog on road;
- blowing sand on road;
- blowing snow on road;
- hail;
- high wind; and
- heavy rain/sleet.

These are all safety considerations and this information is critically important for night drivers. The information is often location specific, depending upon the density of the sensors and the capability of the forecaster. This information is also capable of being disseminated via the telephone by using recorded messages.

Colorado

Colorado, which collects data from as many as 88 weather stations installed around the state, in addition to information gathered from the NOAA, the Colorado State Patrol, and verbal reports from others, disseminates data by fax. Colorado provides fax reports several times a day, automatically, to a list of user agencies. These include freight hauling companies, ports of entry, visitor centers, ski areas, radio stations, and television networks. Reports are generated more frequently during the winter than summer. In general, faxes are sent to subscribers who pay for the service. However, faxes can be sent to non-subscribers. The same data can be made available via E-mail or telephone.

Iowa and Illinois

Both Iowa and Illinois are producing a homepage for the Internet tailored to the needs of the travelers in specific locales. Currently these pages include such information as local area maps, tourist attractions, parking availability, tourist amenities, and weather information. The Internet is a convenient way to widely distribute specific and timely information and the population of users is rapidly growing.

Nevada, Utah, and Georgia

Several states respond to weather dangers by suggesting that drivers reduce their speed (Nevada, for ice on the road, and both Utah and Georgia for reduced visibility due to fog). This concept involves using a radar sign that flashes back the motorist's speed and suggests a lower speed based on weather conditions ahead. For example, the radar sign may flash, "You are going 61 mph, 35 mph is better for the icy road ahead." Such warning signs are relatively inexpensive, are mounted on trailers, and are quickly positioned as the weather dictates.

Several other states conducted extensive studies of various aspects of weather data collection and dissemination. Two of these are discussed in more detail below.

Virginia

Virginia conducted an inventory of the weather data collection and acquisition activities of a range of state agencies having a need for weather-related information. Weather problems of particular concern in Virginia include flooding, heavy snowfall, and damaging winds. These conditions require planning and pre-event deployment of a wide range of state agencies. While Virginia recognizes that the acquisition and dissemination of weather reports, data, and forecasts are costly, concern for public safety requires state government to obtain and disseminate this information.

Virginia found that virtually all weather information originates from NEWS. Private vendors purchase and tailor weather data and resell the product based on an individual client's needs. Most state agencies combine media-based sources of weather information (e.g., "The Weather Channel" or emergency bulletins) with data provided by vendors (who repackage NEWS data) to meet their weather related needs. NEWS data are usually free to government agencies that have a legitimate and justifiable need for the information. Some state agencies require specific weather data that focus on specific topics. For example, pavement surface conditions are of particular interest to the Virginia Department of Transportation and conditions in the upper atmosphere are of particular interest to Virginia pilots. These specialized needs are being met through the collection of original data by the agencies.

The study found two agencies that were dissatisfied with the accuracy and immediacy of their current sources of weather information. Both considered the problem to be primarily one of coordination and cooperation, rather than data collection. One agency suggested that it become the central reformatting and distribution point for weather data for the entire state.

More generally, the study found that numerous Internet sites provide weather data, some updated as often as every 15 minutes. The study concluded that state agencies could improve their acquisition and dissemination of weather data by combining existing resources (eliminating duplication) and through the deliberate sharing of existing information.

Missouri

Missouri recognizes that there is a widespread need for real-time weather and road condition data by a broad constituency of state agencies, private industry, and the public. The study concluded that technology is capable of supporting a real-time weather and road condition-reporting network. In addition, demand for weather and road condition data will increase as individuals become more familiar with the use of real-time information in general. The study recommends the implementation of a Missouri Weather Network. This network will combine aviation weather data collection facilities that are part of the aviation community's Automated Weather Observation System (AWOS) and FAA weather sensors, with the surface transportation oriented Road Weather Information System (RWIS) locations. Additional AWOS (18) and RWIS (over 40) locations were identified and are recommended as part of the study. The combined data are to be centrally consolidated and disseminated by the existing DOT computer support center (suitably modified and expanded).

AIRPORT MANAGERS

Both the Amarillo and Lubbock Airports use weather sensors to evaluate the potential for ice, snow, or sleet covering runways thus making them hazards for arriving and departing aircraft. The sensors monitor both surface and subsurface temperatures. Additionally, the sensors monitor wind direction, wind speed, humidity, and precipitation. A central processing unit at the airport processes the data which users can poll via a modem and telephone line.

Airport maintenance crews use these systems decide whether to initiate runway deicing procedures.

TEXAS MESONET METEOROLOGISTS

Texas A&M University's Department of Meteorology faculty has proposed a plan for a mesoscale meteorology monitoring network (MesoNet) to increase the geographical density of weather observation sites in Texas. This plan, similar to a MesoNet currently in place in Oklahoma, is designed to enhance the quality of weather reports and forecasts developed for Texas users. This system will serve a variety of public and private users in diverse areas such as air quality, water quality, agriculture, power generation, energy transmission, transportation, construction, chemical processing, civil defense/emergency management, recreation, and education.

The MesoNet staff is interested in adding aviation weather services to the list of services provided to public and private users. To accomplish this requires upgrading sensor sites to include visibility and cloud height measurements. This upgrading will increase the cost of site installation.

Figure 6 shows the currently envisioned surface station configuration. Figure 7, taken from the original Department of Meteorology proposal, shows surface weather stations and upper air stations (balloons or radar profiler) currently used by the NWS. The figure also shows the stations currently included in the Oklahoma MesoNet System. Figure 8 shows the sites planned

for the Texas MesoNet. This figure shows that the stations can locate, define, and track smaller-sized weather events.

Figure 7 refers to the MesoNet surface stations, instrumented radio towers, and radar and an acoustic profiler planned for Texas. The sensing capability of each station type is described in Table 1. The planned equipment does not provide for sensing cloud height, visibility, precipitation, or the presence of lightning. These deficiencies limit the value of the observations to pilots.

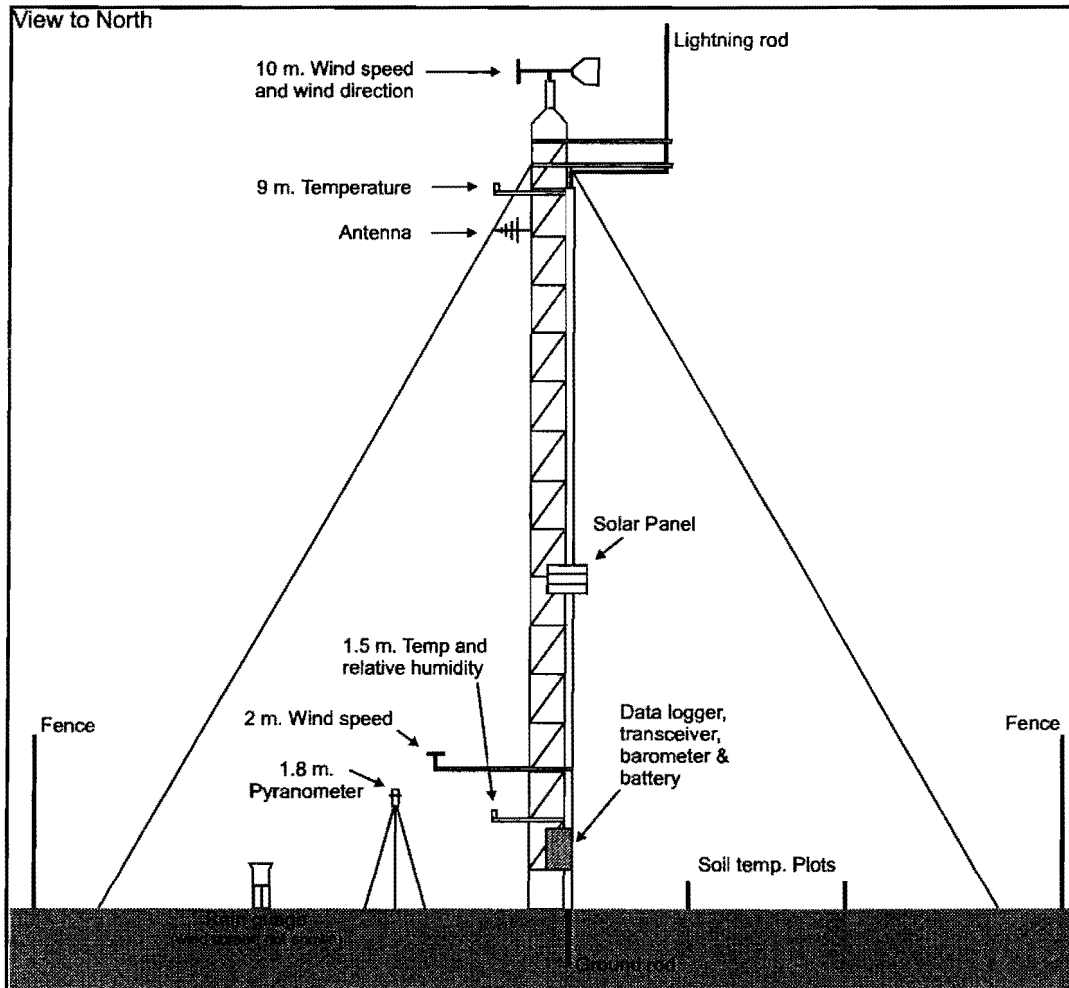


FIGURE 6. MesoNet Surface Station Configuration.

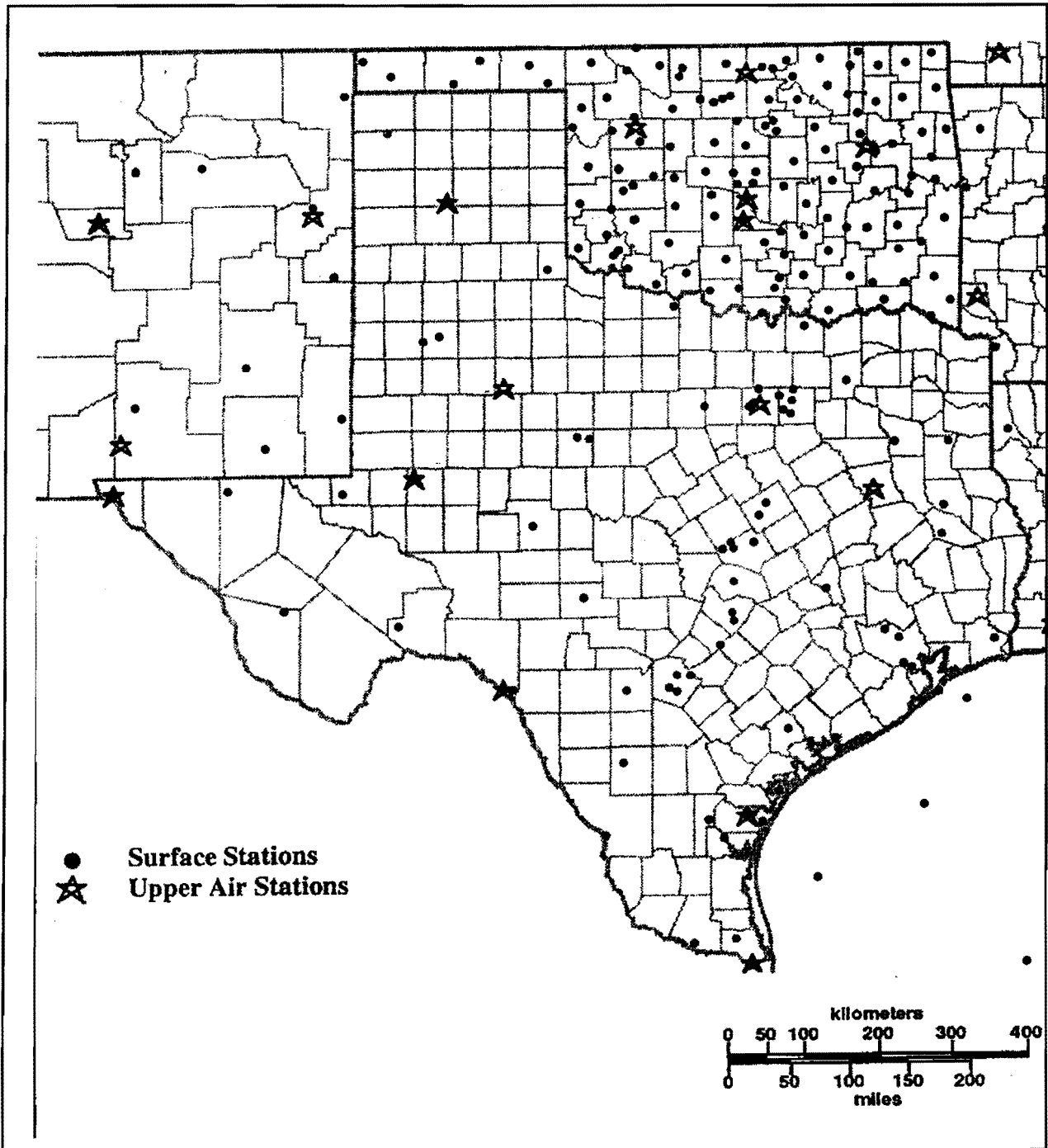


FIGURE 7. Existing Surface Weather Stations and Upper Air Stations Employed by the NWS.

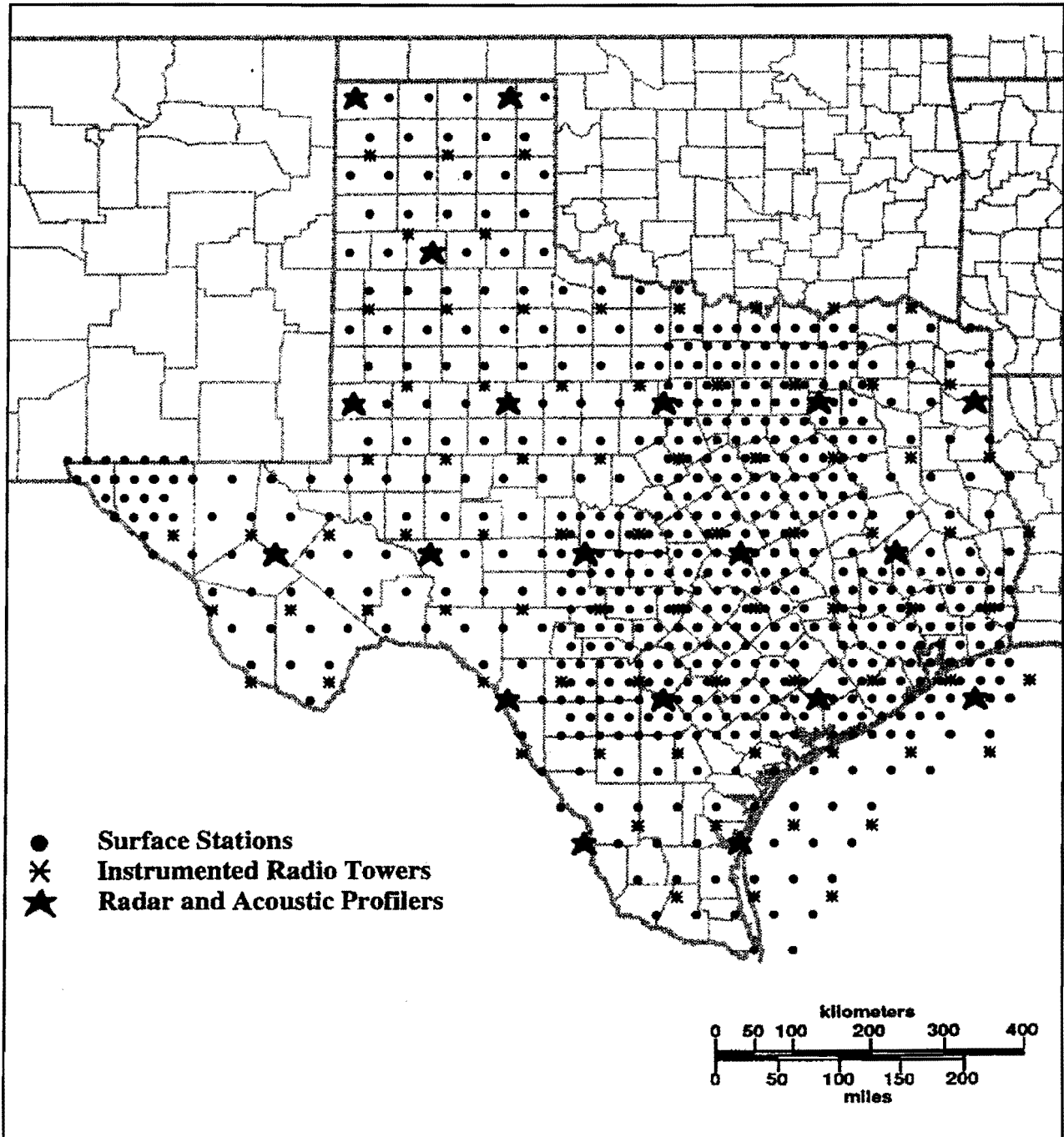


FIGURE 8. Proposed Sites for the Texas MesoNet System.

TABLE 1
Parameters Measured at Surface Stations

Parameter	Height	Accuracy	Resolution	Duration ¹
STANDARD				
Wind speed and direction ³	10 m	2% rdng. ²	0.03 m/s	5 minutes
		3°	0.05°	5 minutes
Air temperature	1.5 m	0.35°C	0.01°C	5 minutes
Relative humidity	1.5 m	3%	0.03%	5 minutes
Barometric pressure	0.75 m	0.4 mbar	0.01mbar	5 minutes
Precipitation ⁴	0.6 m	1% rdng. ²	0.25 mm	5 minutes
Solar radiation	1.8 m	5% rdng. ²	0.23 W/m ²	5 minutes
Soil temperature	-0.1 m	0.5°C	0.03°C	15 minutes
SUPPLEMENTAL				
<i>Inland</i>				
Wind speed	2 m	2% rdng. ²	0.25 m/s	5 minutes
Air temperature	9 m	0.35°	0.03°C	5 minutes
Soil temperature	-0.05, -0.30 m and various	0.5°C	0.03°C	15 minutes
Leaf wetness	0.5 m	tbd ⁵	tbd ⁵	15 minutes
Pan evaporation	Surface	tbd ⁵	tbd ⁵	15 minutes
Soil moisture	Various	tbd ⁵	tbd ⁵	tbd ⁵
<i>Sea and shore</i>				
Sea surface temperature	Surface	0.5°C	0.03°C	2 minutes
Wave height (off shore)	Surface	tbd ⁵	tbd ⁵	tbd ⁵
Current, speed and direction	tbd ⁵	tbd ⁵	tbd ⁵	2 minute vector
Salinity	tbd ⁵	tbd ⁵	tbd ⁵	tbd ⁵
Tide	tbd ⁵	tbd ⁵	tbd ⁵	5 minutes

¹ Values to be averaged for these durations

² rdng. - value of parameter measured

³ Sensor should be removed from the nearest obstruction by at least ten times its height, and derived data from wind sensors include:
Average wind run (arithmetic average speed) and standard deviation of mean
: Vector wind speed and direction and standard deviation of each
Maximum speed (for 3-second sampling time).

⁴ Sensor should be removed from the nearest obstruction by at least four times its height, and accumulative rainfall recorded for reporting.

⁵ tbd. - To be determined.

RAILROAD COMPANIES

Other than informal, or personal, measurements, railroad companies in Texas do not monitor the weather.

PEOPLE AND ORGANIZATIONS INTERVIEWED

The research team interviewed several people involved in all facets of weather data collection and dissemination. These interviews provided independent and divergent overviews of the entire process. There was almost universal agreement that there is a trend toward automated sensing, forecasting, and distribution of weather data.

Some individuals interviewed included:

Dave Schwarz

(282) 337-5074
Weather Forecast Office
National Weather Service
Houston-Dickenson, TX

Bob Johnson

(800) WX-BRIEF
Flight Service Station
Federal Aviation Administration
Conroe, TX

Chuck Morrow

(817) 222-4221
ASOS/AWOS Program Manager, SW Region
Federal Aviation Administration
Fort Worth, TX

Lee Lawry

(520) 806-7464
Global Atmospherics, Inc.
2705 East Medina Road
Tuscon, AZ 85706

Tim Borson

(817) 652-7810
National Transportation Safety Board
Arlington, TX 76011

Ernest Sessa

(410) 667-7069
Systems Management Inc.
P. O. Box 238
Hunt Valley, MD

Don Anderson

(801) 753-2342
Campbell Scientific, Inc.
815 West
Logan, UT

Leon Thomas

(703) 818-4971
GTE DUATS

George Dozier

(806) 748-4445
Lubbock District
Texas Department of Transportation

Wayne Williams

(806) 775-2040
Lubbock International Airport

Gary L. Sickler and Bruce E. Gammon

(409) 845-7671
Department of Meteorology
Texas A&M University

CHAPTER 3. WEATHER SENSOR DATA INVENTORY

AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)

One sensor used by the NWS is the Automated Surface Observation System (ASOS). These are sensor systems, mainly at airports, scattered over the nation, including Texas. Figure 9 shows the existing ASOS sites in Texas.

Observations are made continuously at ASOS sites. However, the NWS will only poll the sensor on an hourly basis, unless significant changes in weather conditions require polling that is more frequent. Data from many of the ASOS sites are used by the NWS for reporting current weather conditions, as well as producing forecasts. Virtually all ASOS sites are accessible to the public, via telephone, and to the pilot, via a VHF radio, on a continuous basis. Pilots may also obtain the last hourly ASOS observation from a nearby flight service station.

The ASOS reports the following elements:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- basic current weather information (type and intensity);
- obstructions to vision: fog, haze;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character; and
- other data, primarily related to weather trends.

Because ASOS sensors only record these measurements at the observation point, there is some degradation of the weather data product. This is a result of the automated observation system. Deficiencies of the weather data reported by the ASOS sensors includes the inability to describe true visibility, by direction, or nearby thunderstorm(s) with the potential for lightning, gust fronts, turbulence, and hail. However, reduced costs and increased density of weather observation sites are features that out-weigh the deficiencies. Pilots can now use instrument approaches into many airports where before, without weather observers on the ground, they could not. The continuous automated observations, giving the user up-to-date weather conditions, is another valuable feature of the ASOS.

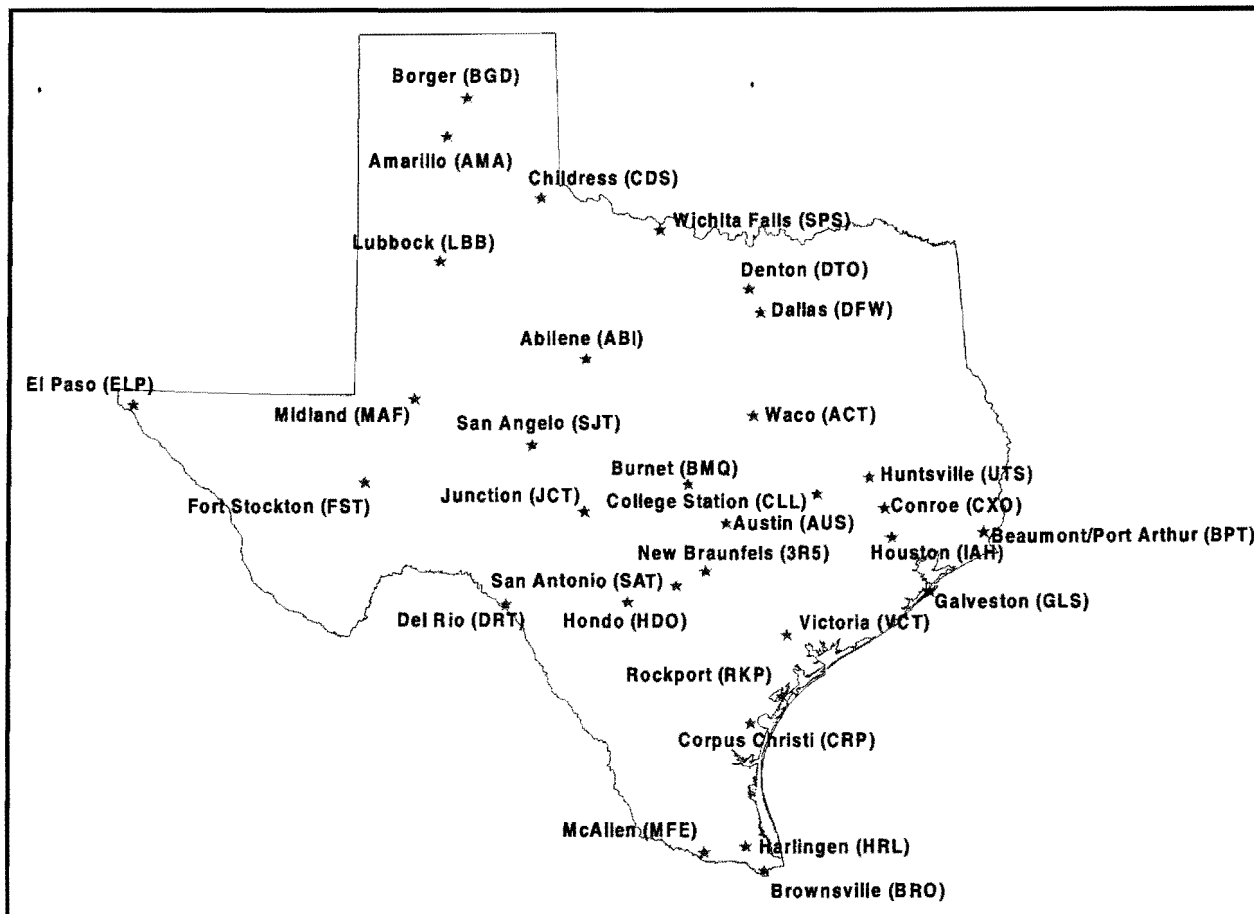


FIGURE 9. NWS ASOS Locations in Texas.

AWOS

AWOS sensors have been installed by the FAA at selected airports around the country. Figure 10 shows the existing AWOS sites in Texas. The map was generated from information in the Airport/Facility Directory and verified through the NWS web site. (1)

There are various types of AWOS sensors, but the AWOS-3 is the only type found in Texas. The AWOS-3 sensors report the following data:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character;
- precipitation accumulation; and
- other data as warranted, including density altitude, variable visibility, and variable wind direction.

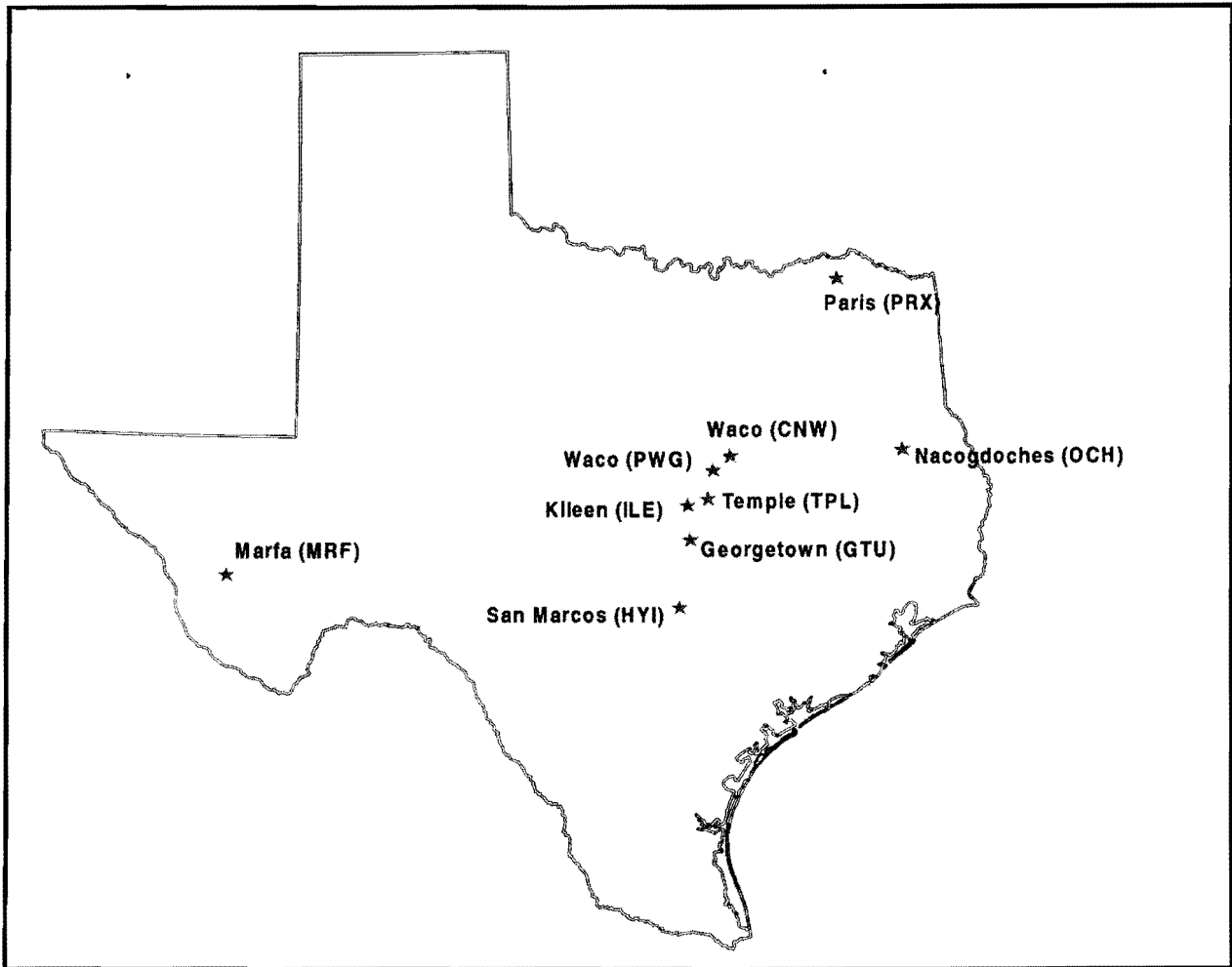


FIGURE 10. FAA AWOS Locations in Texas.

The AWOS sensors are very similar to the ASOS sensors. The NWS also collects data from AWOS sensors for use in reporting current conditions, as well as preparing forecasts.

AUTOMATED METEOROLOGICAL OBSERVING STATION (AMOS)

An Automated Meteorological Observing Station (AMOS) is capable of automatically observing temperature, dew point, wind direction and speed, atmospheric pressure, peak wind speed, and precipitation accumulation. The stations are tied in directly to the FAA observation network. AMOS weather reports are only transmitted when polled by the circuits. AMOS reports can be supplemented by human observers. (1)

Because these sensors are listed in the Aviation Weather Services Advisory Circular (AC 00-45), they are also listed in this report. However, the FAA states that these sensors are obsolete and were replaced by ASOS and AWOS observation sites in Texas. (2)

AUTOMATIC OBSERVING STATION (AUTOB)

The Automatic Observing Station (AUTOB) is an AMOS with the added capability to automatically report sky conditions, visibility and precipitation occurrence. The station is polled at 20-minute intervals, measuring cloud heights only to 6,000 feet AGL. (1)

Because these sensors are listed in the Aviation Weather Services Advisory Circular (AC 00-45), they are also listed in this report. However, the FAA states that these sensors are obsolete were replaced by ASOS and AWOS observation sites in Texas. (2)

LIMITED AVIATION WEATHER REPORTING STATION (LAWRS)

Limited Aviation Weather Reporting Station (LAWRS) are stations, typically located at airports, where human observers report cloud height, weather, obstructions to vision, temperature and dewpoint, surface wind, altimeter setting, and other data. There are only a few sites in Texas and these are shown Figure 11. (3)

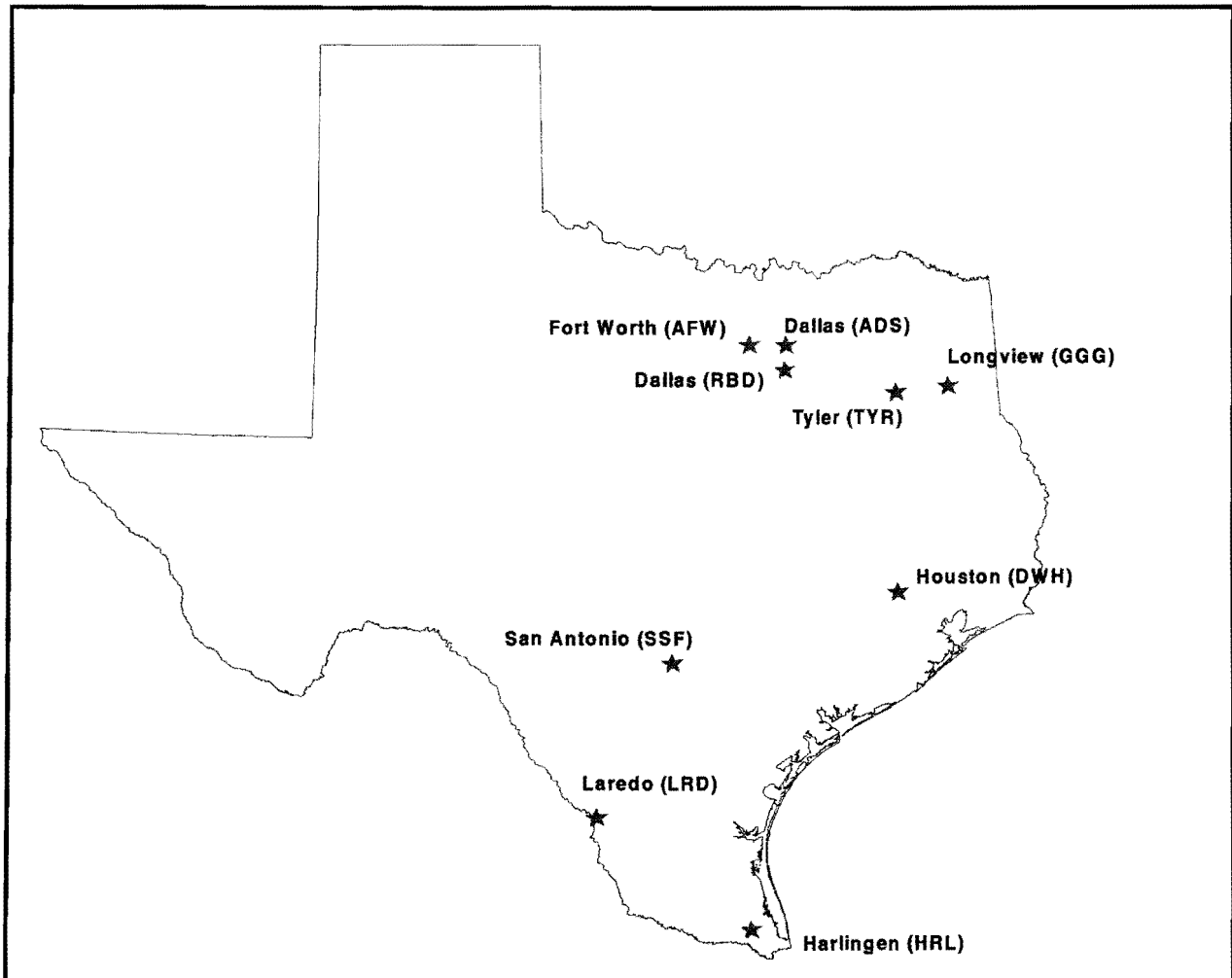


FIGURE 11. LAWRS Locations in Texas.

LLWAS

The LLWAS consists of a center field anemometer with several field perimeter anemometers. The system compares wind speed and direction measurements at the center of the airport to those measurements taken around the perimeter. If significant variation is detected, a wind shear alert is issued. Figure 12 shows the locations of the LLWAS observation sites in Texas. (3)

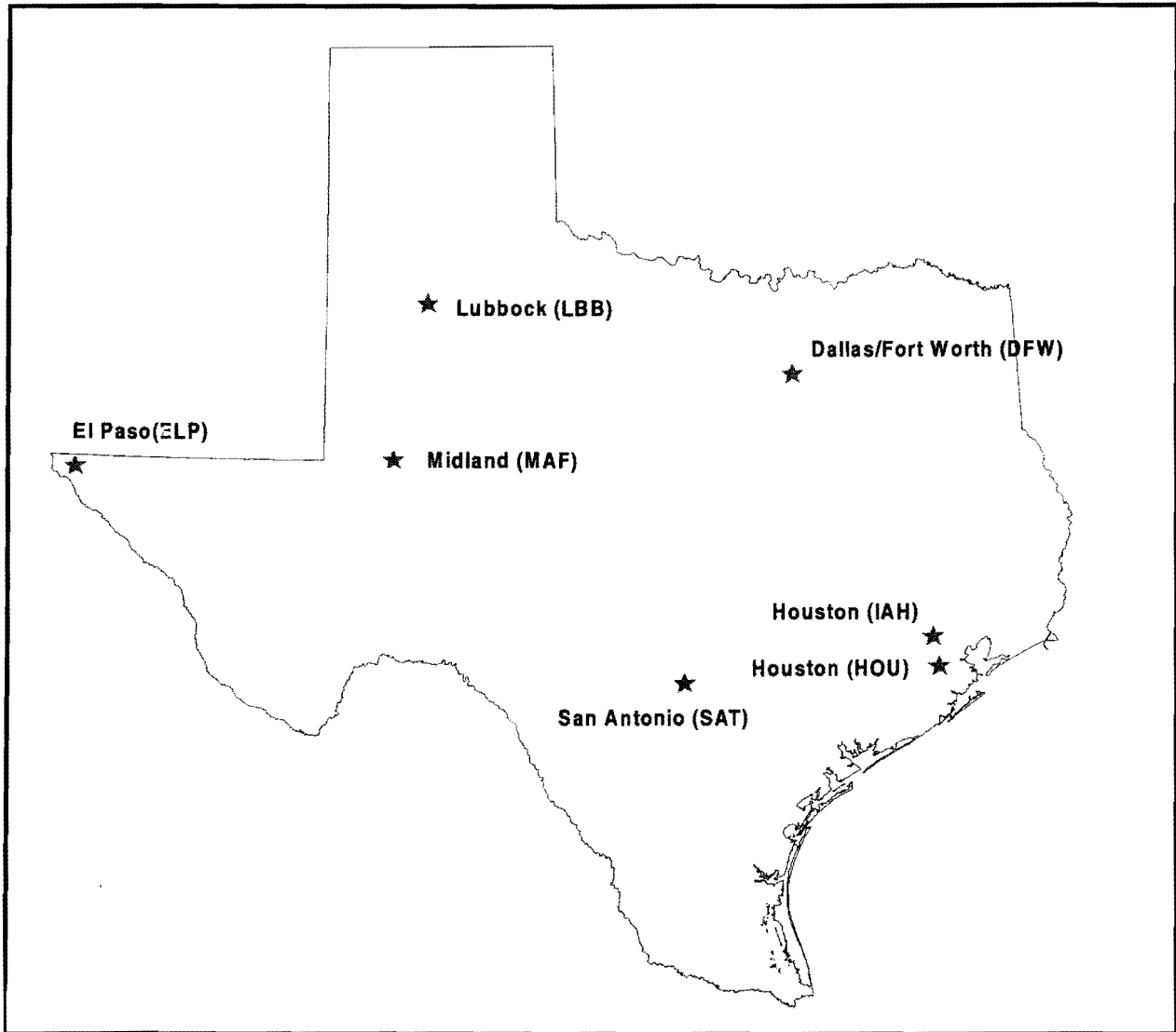


FIGURE 12. LLWAS Locations in Texas.

RWIS

The RWIS consists of remote processing units (RPUs), sensing devices installed along highways, and central processing units (CPUs) installed at highway maintenance facilities. The RPU consists of pavement sensors and other standard weather information sensors. The pavement

sensors measure surface temperature, subgrade temperature, surface condition, the amount of deicing chemical on the pavement, or the freezing point of a wet surface. Other standard weather data includes atmospheric temperature, relative humidity or dewpoint, wind speed and direction, and precipitation.

Several TxDOT districts use RWIS programs to communicate road weather information, and produce forecasts in support of snow and ice control activities. Figure 13 shows the known RWIS sites in Texas. Each district has an independent RWIS configuration. (4)

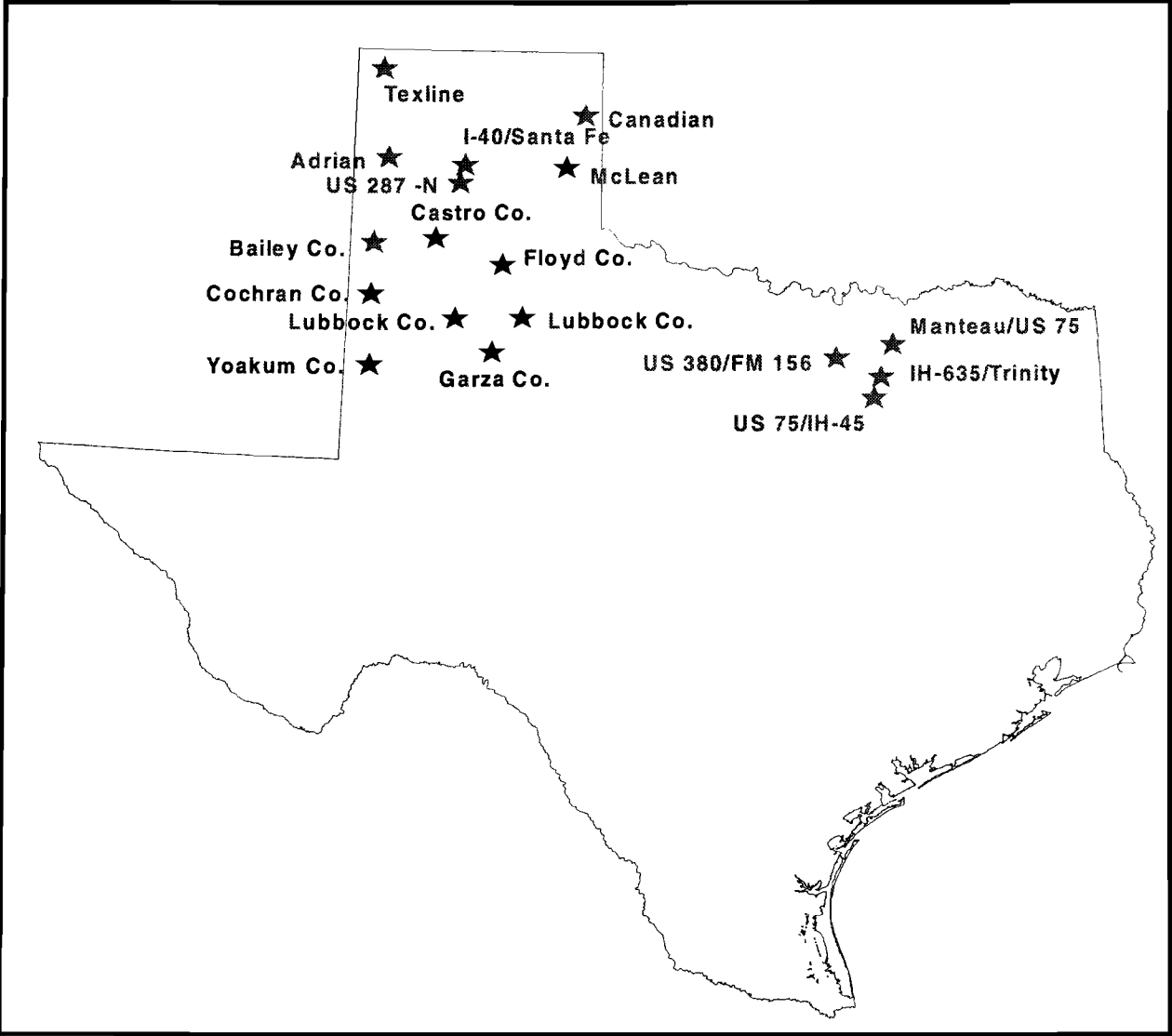


FIGURE 13. RWIS Locations in Texas.

NEXRAD (or WSR-88D)

The NEXRAD uses Doppler technology to detect wind-driven precipitation within clouds. This is useful in predicting the development of tornadoes, flash floods, squall lines, wind, wind shear, and precipitation. Figure 14 shows the locations of NEXRAD sites in Texas.

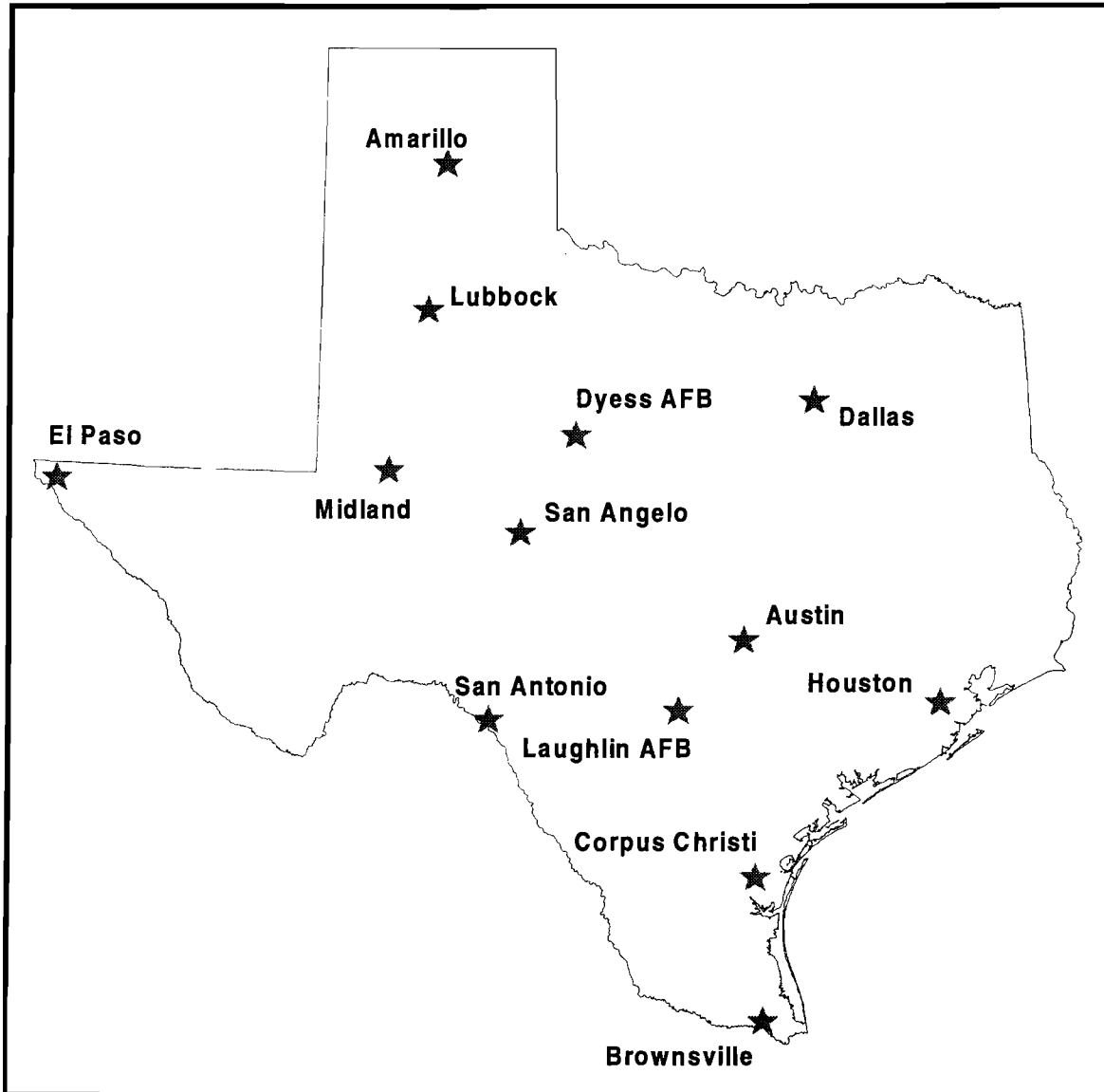


FIGURE 14. NEXRAD Locations in Texas.

TDWR

Four of the largest airports in Texas employ the TDWR that senses and reports wind directions and speeds. As noted previously, this radar scans the extended centerline of selected runways searching for wind shear, either on vertical or horizontal geometrical planes.

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES)

Weather information can also be collected over a broad coverage area by use of Geostationary Operational Environmental Satellites (GOES). GOES are capable of tracking large-scale weather features, and are normally positioned over the Equator to provide a broad view of the U.S. as well as the Pacific and Atlantic area. These are areas where surface observations are not feasible. This is particularly useful in the winter storm and hurricane seasons. Figure 15 shows a typical image produced by the GOES installations. (5)

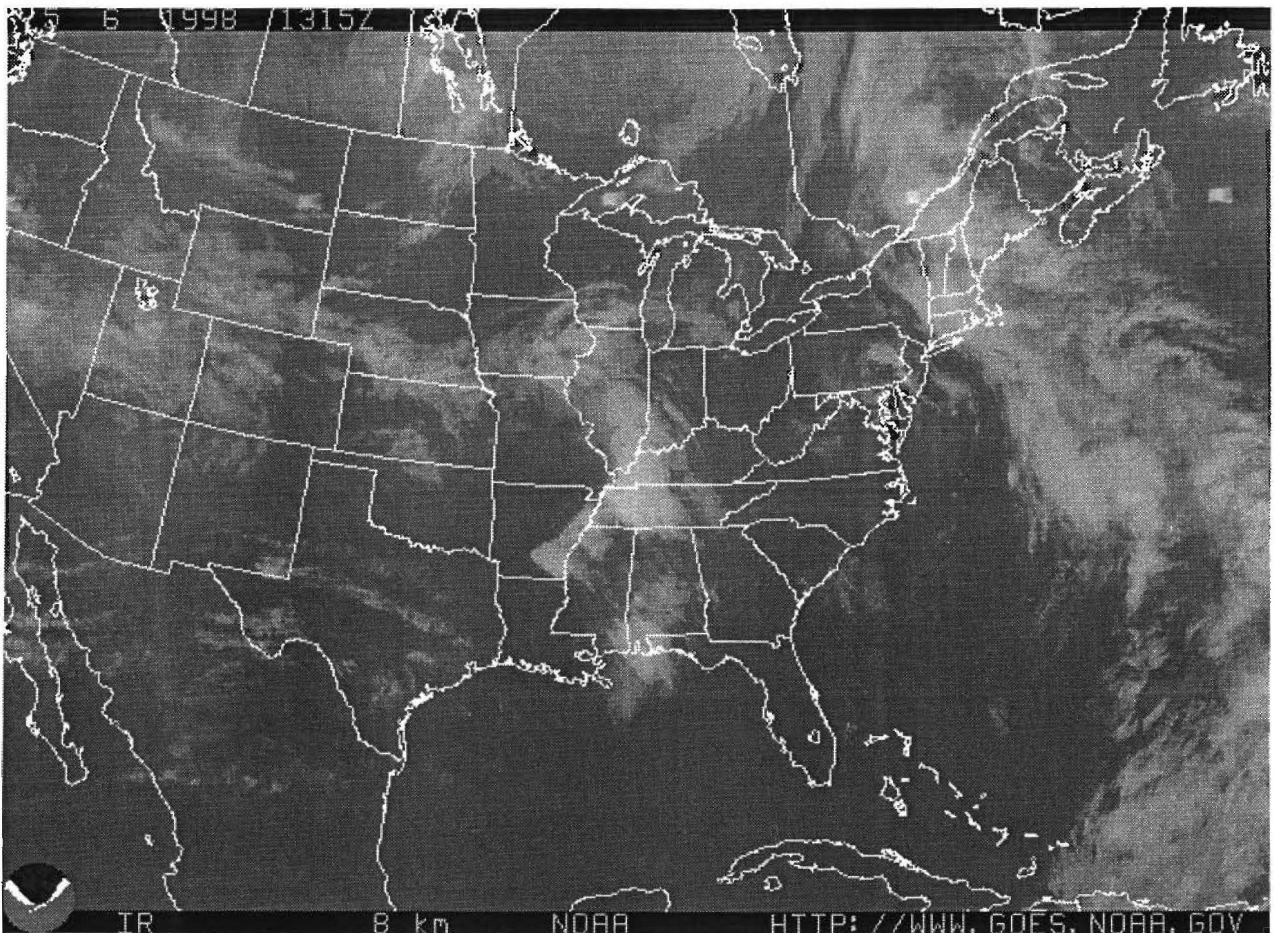


FIGURE 15. GOES Image.

NATIONAL LIGHTNING DETECTION NETWORK (NLDN)

The National Lightning Detection Network (NLDN) is owned and operated by Global Atmospheric, Inc. of Tucson, AZ. These sensors collect real time lightning data that includes location and intensity of lightning activity. The network of sensors is designed to warn users of severe thunderstorm activity for a radius of up to 100 nautical miles. The sensor unit detects cloud-to-ground lightning strikes from the electro-magnetic impulse that is generated by the lightning return stroke. Lightning strike information is then transmitted via satellite to a central processing unit, where it is commercially available. Industries that purchase this value-added information consist of power utilities, telecommunications, forestry, air traffic control, forensic insurance reports, and others. Figure 16 shows the locations of NLDN detectors in Texas. (6)

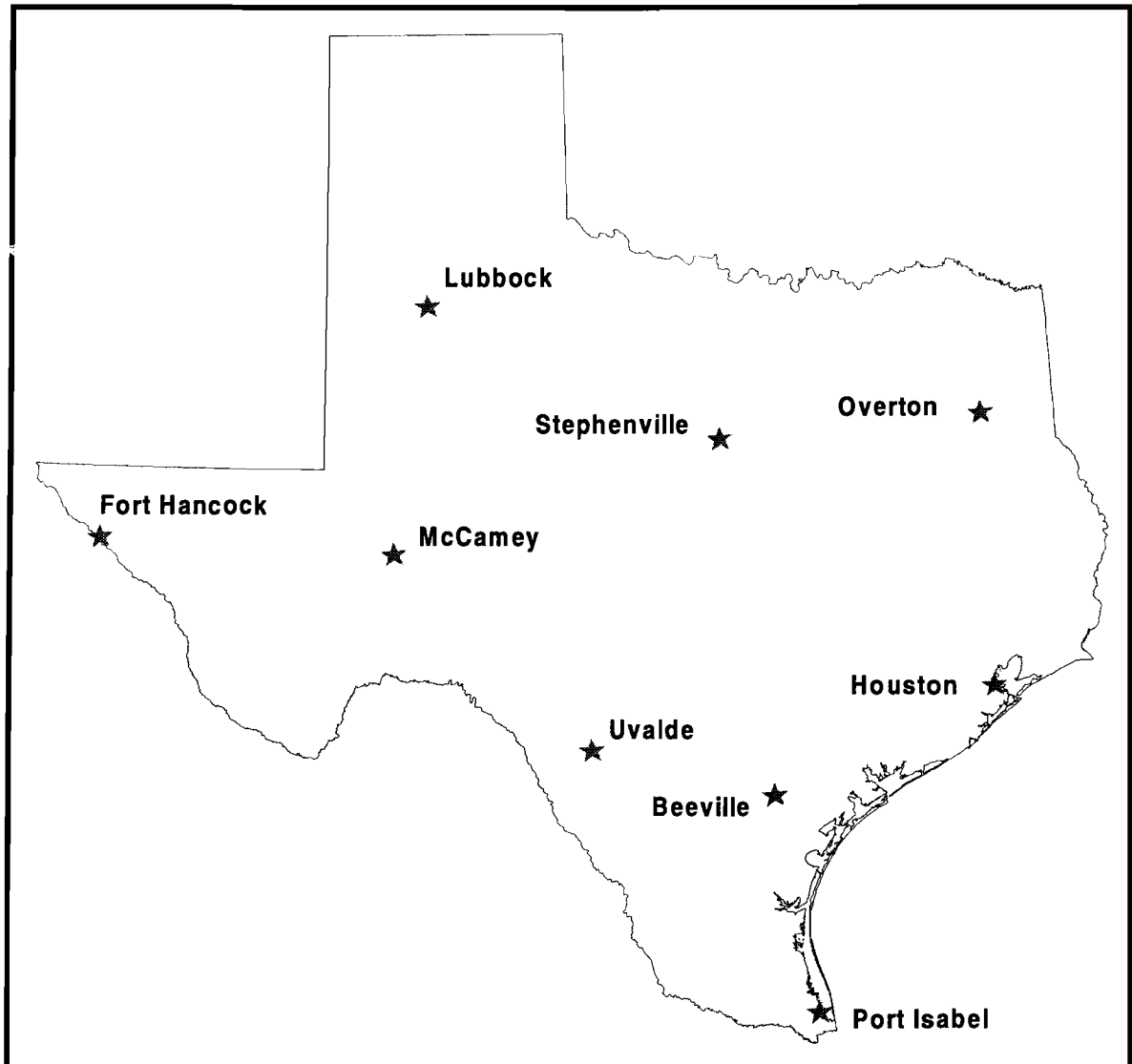


FIGURE 16. NLDN Locations in Texas.

RADIOSONDE

A radiosonde, also known as rawinsonde, is a balloon-borne instrument that produces upper air observations, called soundings. Soundings are vertical profiles of temperature, humidity, and winds in the atmosphere and are taken twice daily at the same times at sites across the world. Only the radiosonde sites in and around Texas are significant in terms of a Texas weather sensor inventory. These sites are shown in Figure 17. (7)

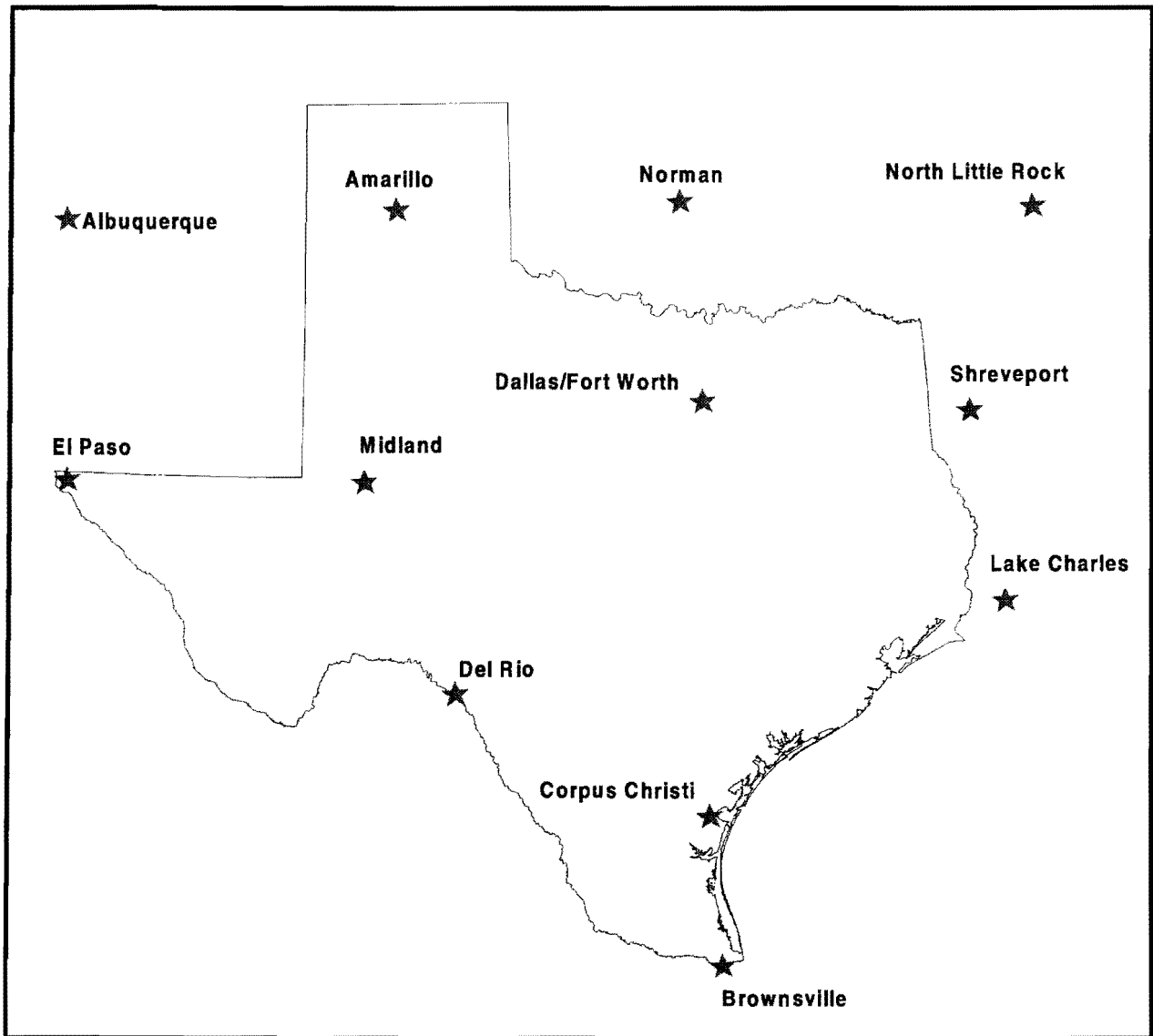


FIGURE 17. Radiosonde Locations in and Around Texas.

WIND PROFILERS

Soundings are also recorded from ground-based devices called wind profilers. A wind profiler is effectively a Doppler radar, pointed straight up, to give a continuous indication of the wind directions and speeds at all levels up to approximately 30,000 feet. As shown in Figure 18, there are two sites in Texas with operational wind profilers—Jayton and Palestine. Other sites, located near Texas are also shown. (8)

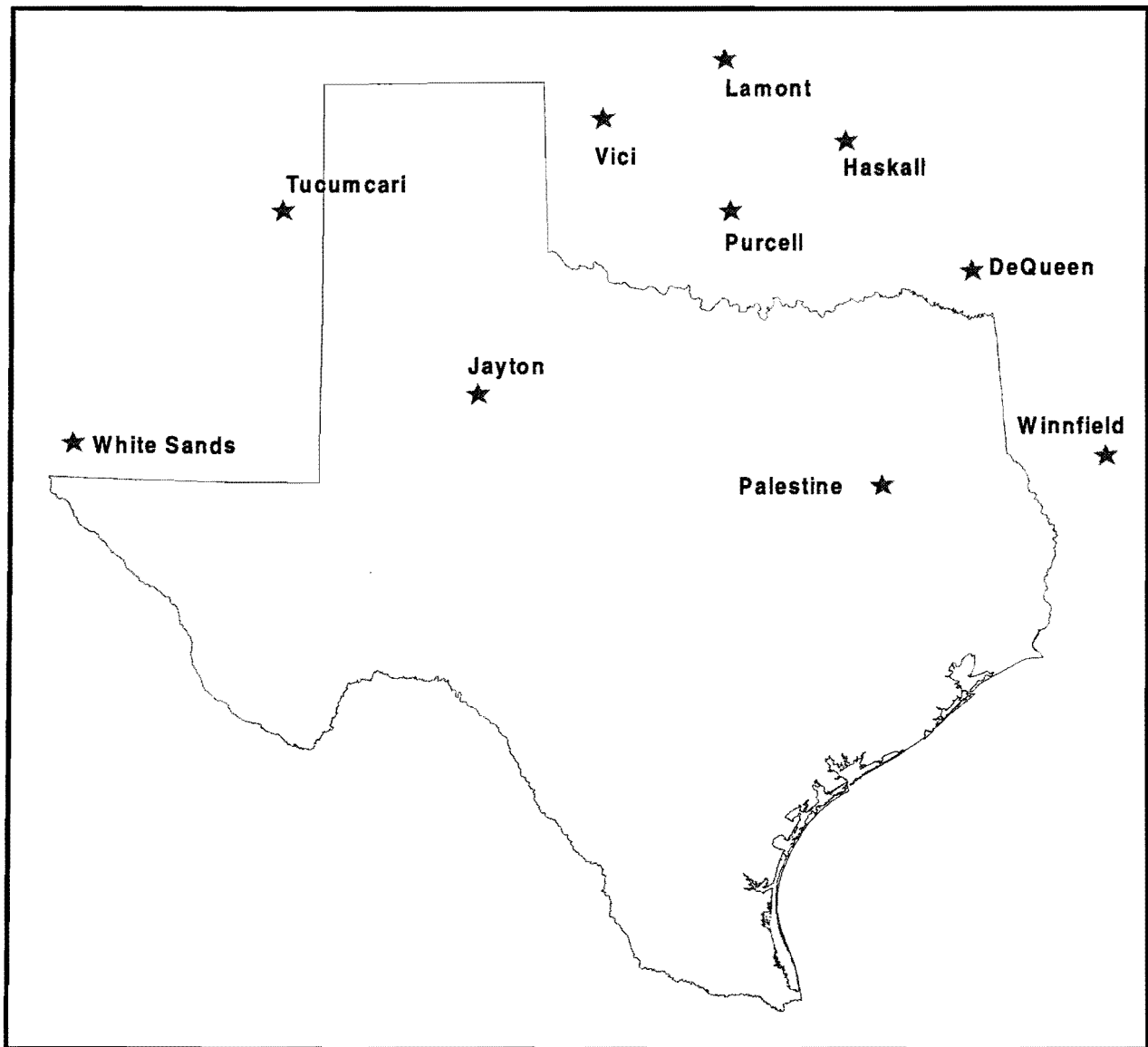


FIGURE 18. Wind Profiler Locations in and Around Texas.

NATURAL RESOURCES CONSERVATION COMMISSION (NRCS)

The Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture has a set of 10 weather stations managed by local NRCS personnel. The location of each sensor is shown in Figure 19. These sensors detect wind speed, wind direction, solar radiation, ambient temperature and humidity, soil temperature, and rainfall. Some sensors collect supplemental data, such as soil temperature, water temperature, and/or water depth. They exist primarily for agricultural applications. For example, data from the Haskell sensor is used by a cotton farmer to run a computer model for irrigation scheduling. (9)

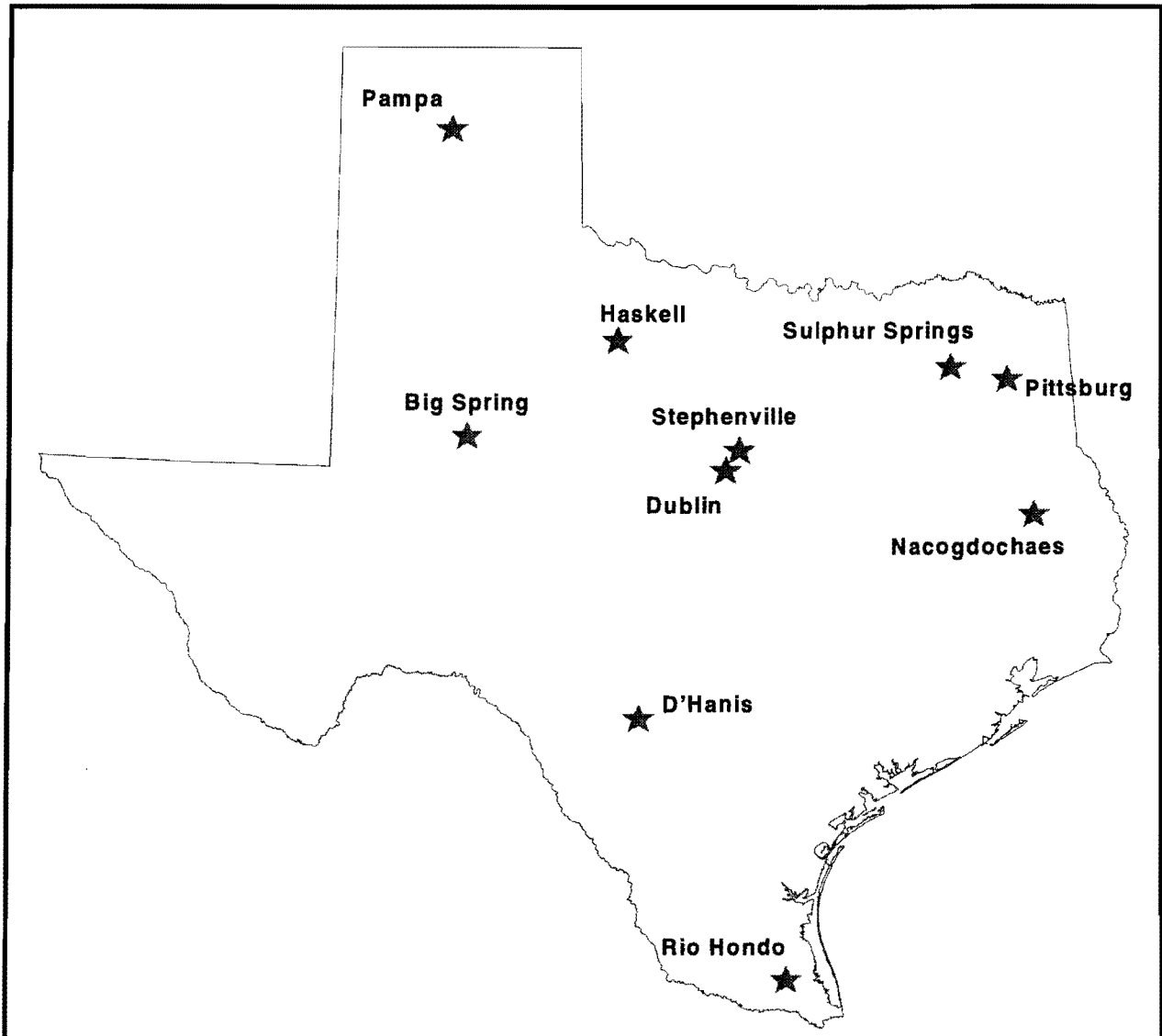


FIGURE 19. NRCS Sensor Locations in Texas.

NATIONAL DATA BUOY CENTER (NDBC)

The National Data Buoy Center (NDBC) is a part of the NWS that develops, operates, and maintains a network of buoy and Coastal-Marine Automated Network (C-MAN) stations. NDBC provides hourly observations from a network of about 60 buoys and 60 C-MAN stations. The stations located in Texas and along the Texas coastal area are shown in Figure 20. All stations measure wind speed, direction, and gust; barometric pressure; and air temperature. In addition, all buoy stations, and some C-MAN stations, measure sea surface temperature and wave heights and periods. (10)

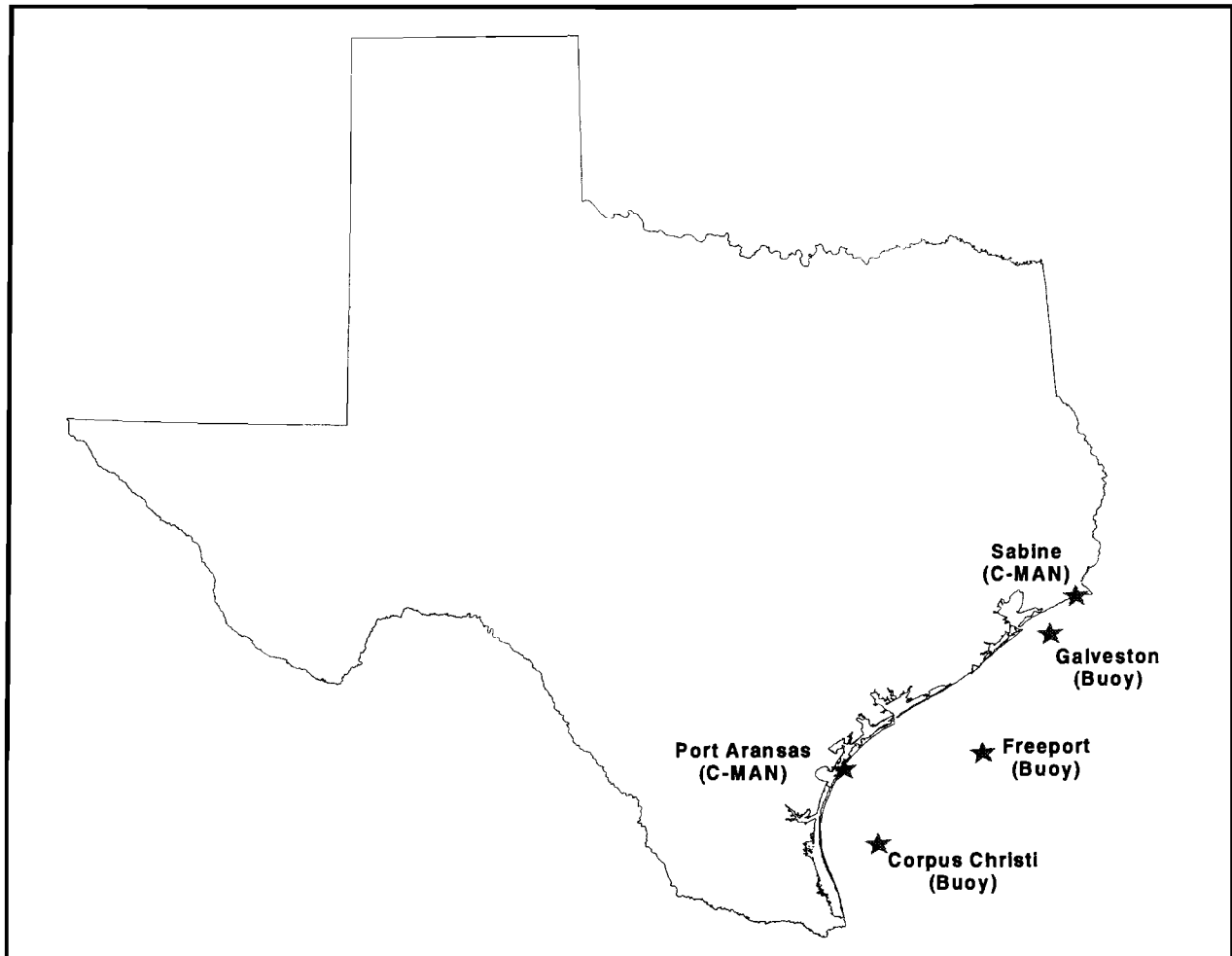


FIGURE 20. NDBC Station Locations in and Around Texas.

UNITED STATES FOREST SERVICE (USFS)

The Wildland Fire Assessment System (WFAS), part of the United States Forest Service (USFS), uses a network of weather sensors to predict susceptibility to wildfires. The WFAS generates national maps of selected fire weather and fire danger components, based on the National Fire

Danger Rating System (NFDRS). NFDRS computations are based on once-daily, mid-afternoon observations (2 p.m. LST) from the Fire Weather Network that is comprised of about 1,000 weather stations throughout the U.S. and Alaska. The weather stations located in Texas are shown in Figure 21. The sensors measure temperature, relative humidity, wind, and precipitation. The observations that are reported to the Weather Information Management System (WIMS) where they are processed by NFDRS algorithms. Many of the stations are seasonal and do not report during the off season. WFAS queries WIMS each afternoon and generates maps from the day's weather observations. Each afternoon Fire Weather Forecasters from the NWS also view these observations and issue trend forecasts for fire weather forecast zones. (11)

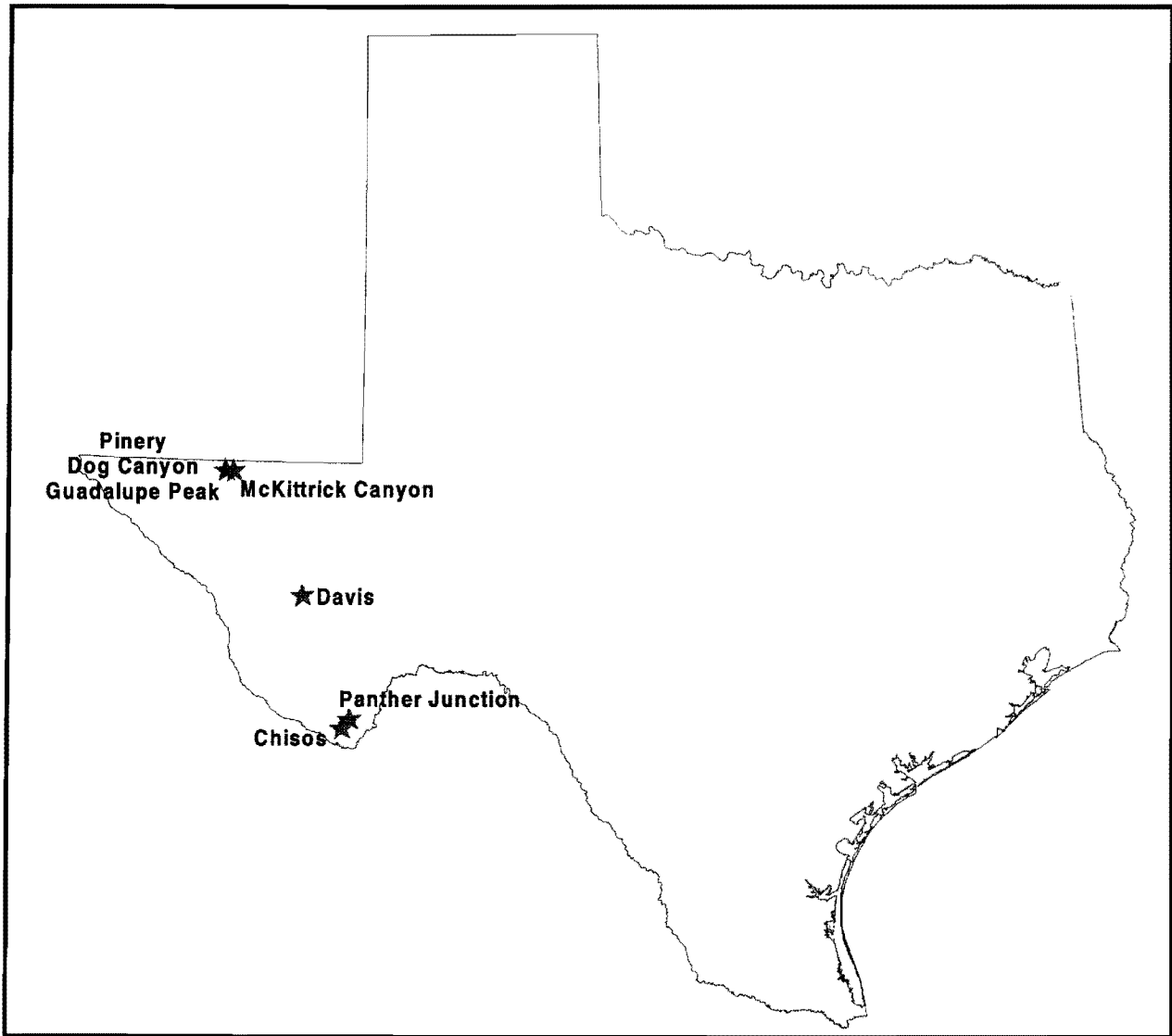


FIGURE 21. WFAS Sites in Texas.

TEXAS FOREST SERVICE (TFS)

Using data generated from USFS, the Texas Forest Service (TFS) maintains sensors in East Texas. The East Texas sensors are depicted in Figure 22 and support fire protection for state parks and national forests. The sites are depicted separately from the WFAS sites because data from these sensors are not transmitted to WIMS for processing. (12)

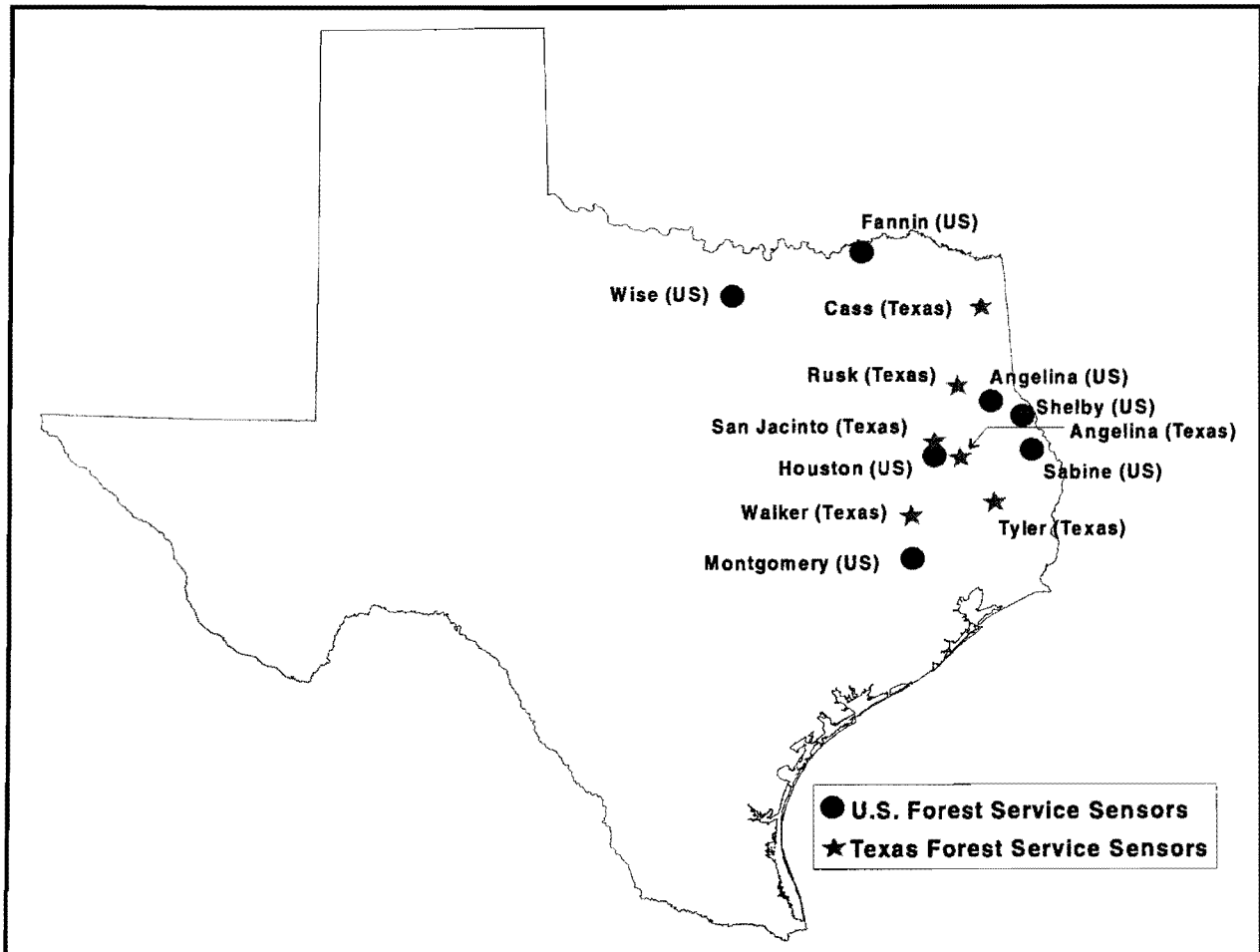


FIGURE 22. TFS and USFS Sensor Locations in East Texas by County.

NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC) records temperature and precipitation data in a historical database for over 600 locations in Texas. The data are often recorded by volunteers on a daily basis and forwarded to NCDC at the end of the month. Typical observers include: the state of Texas, cities or municipalities, radio stations, the U.S. Corps of Engineers, public utilities, and miscellaneous or individual observers. Although the observation network is broad, the information is not submitted in a timely fashion that is useful for forecasting purposes. Figure 23 shows the locations of the NCDC observers in Texas. (13)

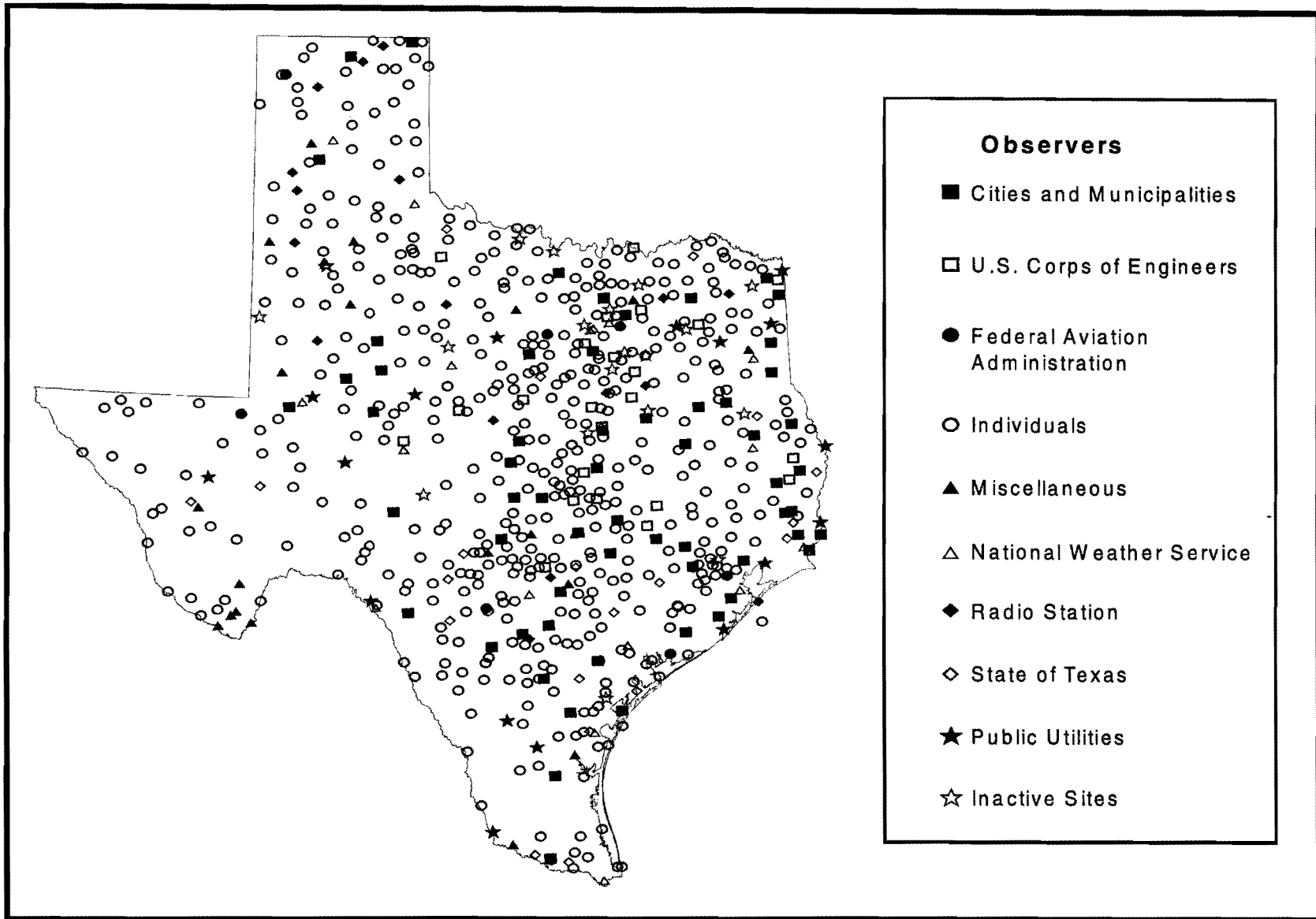


FIGURE 23. NCDC Observers in Texas.

CHAPTER 4. WEATHER DISSEMINATION INVENTORY

The most pronounced need resulting from interviews with weather professionals was a desire to provide the best possible quality of weather information to the user at a minimum expenditure of man-time. This means automating the collection, analysis, and dissemination of weather data. This trend is evident at both the NWS and at the FAA, but is more evident at the NWS. The trend is strong at every level, from the collection of data using the ASOS, to the analysis using the AWIPS, to the distribution of Meteorological Routine Aviation Reports (METAR) and Terminal Aerodrome Forecasts (TAFs) through video screens furnished by commercial providers. The new systems are justified as providing improved safety, greater airspace capacity, and more efficient routing systems.

The NWS and the National Environmental and Satellite Data and Information Service (NESDIS) are both agencies of the NOAA in the Department of Commerce. The FAA, on the other hand, is a part of the Department of Transportation. The NWS, NESDIS, and FAA must work together to provide timely and pertinent weather information, especially for the aviation user. In addition, the use of telephones, modems, VHF radios, AM radios, television, facsimile, and other modes have clouded the inventory of dissemination modes. Consequently, categories and groupings are not always perfectly distinct.

NWS

The NOAA is one of the leading scientific agencies in the U.S. government. Among its six major divisions are the NESDIS and the NWS.

The NWS collects and analyzes meteorological and hydrological data, and subsequently prepares forecasts on a national, hemispheric, and global scale. The following is a description of the NWS facilities tasked with these duties.

National Meteorological Center (NMC)

The National Meteorological Center (NMC), located in Washington D.C., is the focal point of the NWS's weather processing system. From worldwide weather reports, NMC prepares weather analysis charts and guidance forecasts for use by NWS offices and other users. A few charts and forecasts are manually prepared by meteorologists, however the majority are computer generated. Some NMC products are specifically prepared for aviation. For example, the Winds and Temperatures Aloft Forecast. Figure 24 shows the locations of the Winds and Temperatures Aloft Forecast sensor stations in and around Texas.

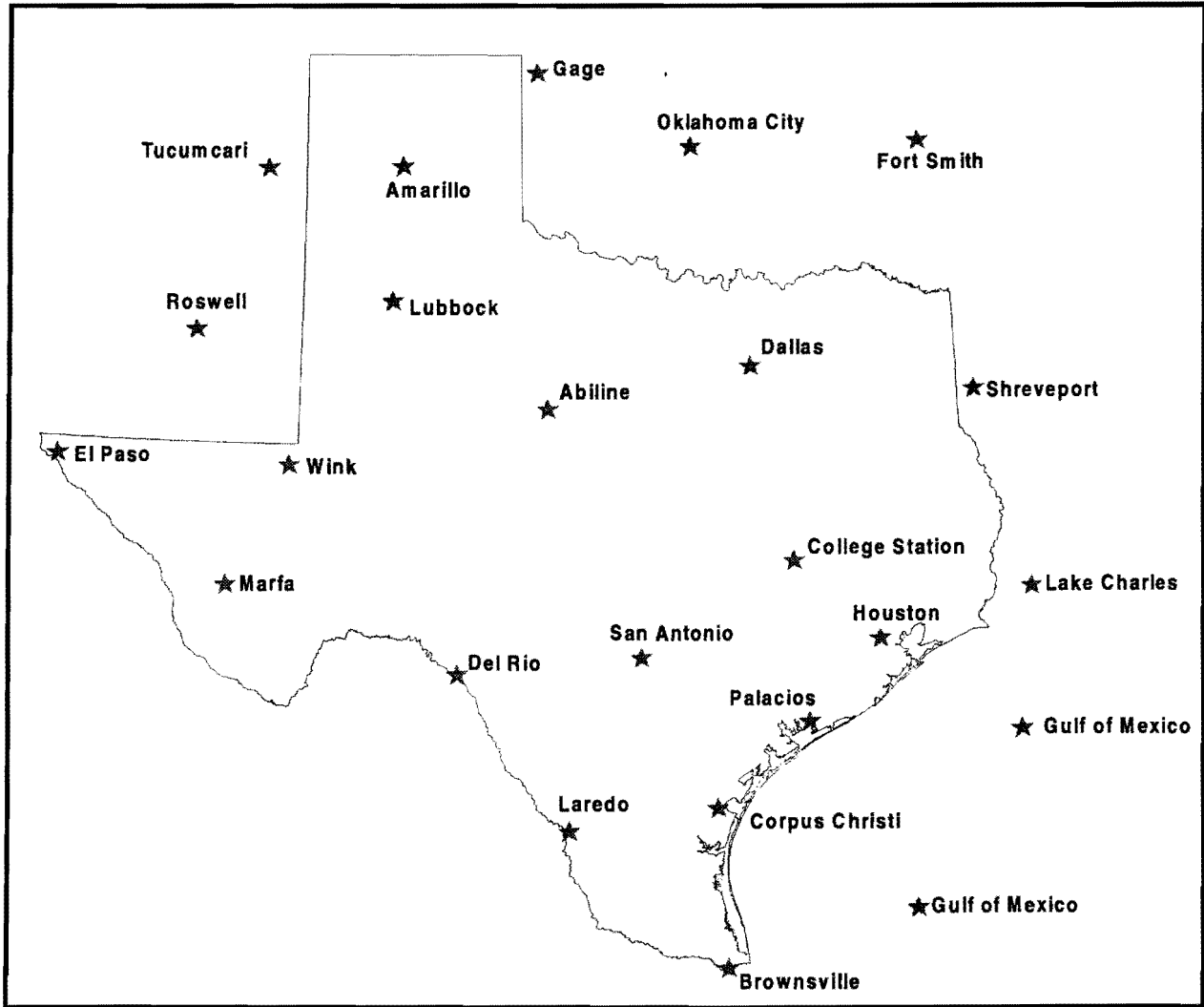


FIGURE 24. Winds and Temperatures Aloft Sensor Sites in and Around Texas.

National Severe Storms Forecast Center (NSSFC)

The National Severe Storms Forecast Center (NSSFC) prepares and issues convective outlooks and forecasts, in addition to severe weather watches, for the contiguous 48 states. NSSFC is located in Kansas City, MO, at the heart of the area most frequently affected by severe thunderstorms.

National Hurricane Center (NHC)

The National Hurricane Center (NHC), located in Miami, FL, issues hurricane advisories for the Atlantic, the Caribbean, the Gulf of Mexico, the eastern Pacific, and adjacent land areas. The center also develops hurricane-forecasting techniques and performs hurricane research. The Central Pacific Hurricane Center in Honolulu issues advisories for the central Pacific Ocean.

National Aviation Weather Advisory Unit (NAWAU)

The National Aviation Weather Advisory Unit (NAWAU), located in Kansas City, MO, is dedicated to aviation. Meteorologists in this unit prepare and issue aviation Area Forecasts and In-Flight Weather Advisories (e.g., AIRMET and SIGMET and Convective SIGMETs) for the contiguous 48 states.

WFO

A Weather Service Office (WSO) prepares and issues public forecasts and weather warnings and provides general weather service for their local areas. Some WSOs provide formal pilot weather briefings, however, the majority do not. Pilots can still receive specifically requested weather information from those offices that do not offer formal briefings. The NWS is currently undergoing a major Modernization and Associated Restructuring (MAR) in which the present field offices will be realigned into a new type of office. This office will be known as a Weather Forecast Office (WFO). Figure 25 shows the regions covered by the planned WFOs. These new offices will replace the present WFO/WSO concept and are designed to take advantage of WSR-88D Doppler Radar and other new technology to improve weather services. The WFOs will be staffed primarily with meteorologists and serve smaller areas than current WSFOs. Completion of the second stage of the MAR is expected by the late 1990s.

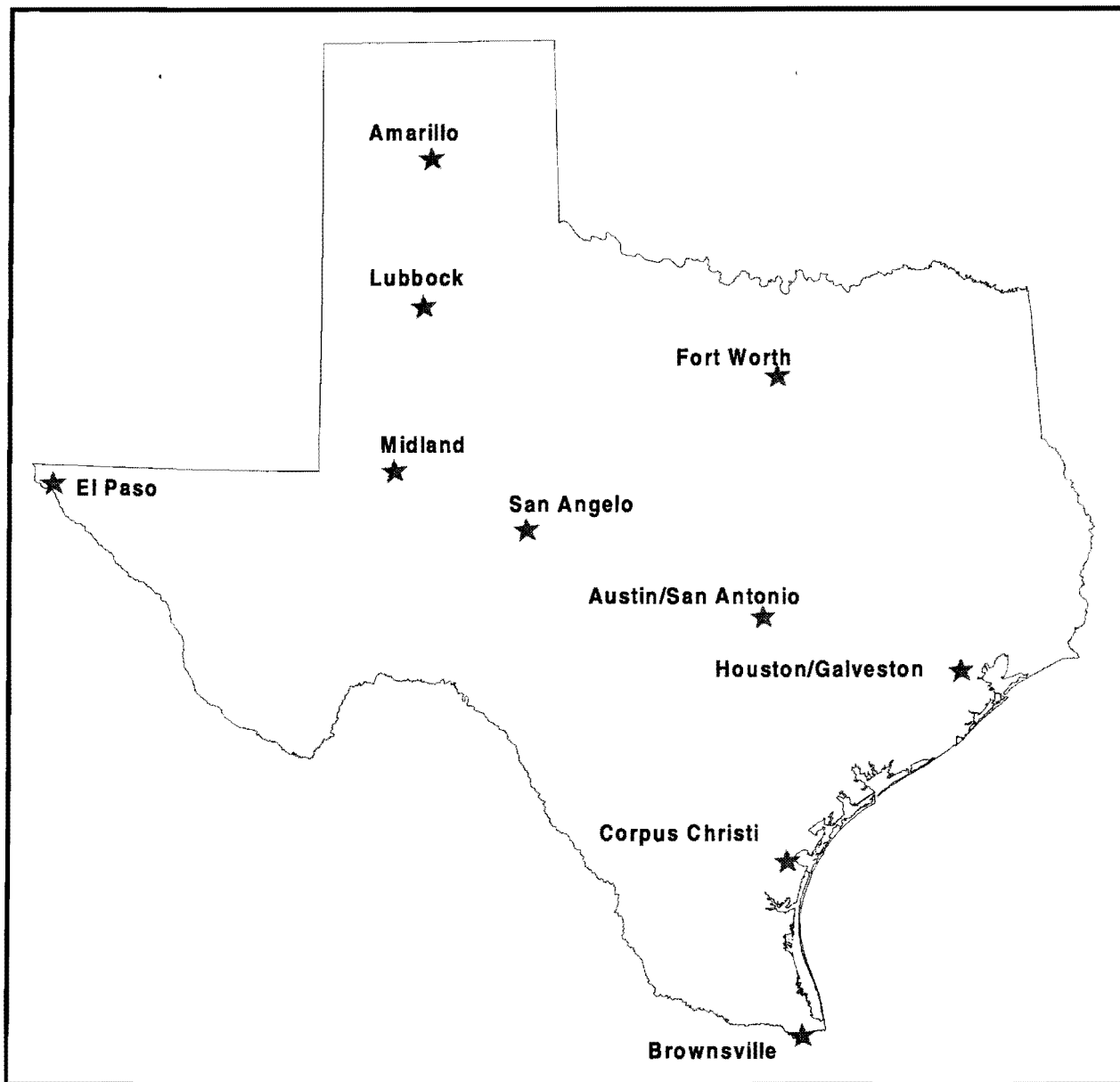


FIGURE 25. Planned Sites for the New WFOs in Texas.

Additionally, the WSFO office in San Antonio (SAT) currently provides the Coastal Marine Forecasts (CMFs) for the entire Texas Coast. In the very near future, the NWS will prepare CMFs at three WFOs in Texas (Brownsville, Corpus Christi, and Houston-Dickinson) and the WFO in Lake Charles, LA. The Texas Coastal area will be covered by four WFO offices as shown in Table 2. Forecasts are issued four times each day and cover the specific part of the Texas Coast as shown. In general, a detailed forecast for the next twenty-four hours is prepared, a

less detailed forecast for the subsequent twenty-four hours is prepared and a generalized outlook for the three days after that is summarized.

TABLE 2
Planned WFOs and Areas Covered

WFO	Coastal Area Covered
Brownsville	From Brownsville to Baffin Bay
Corpus Christi	From Baffin Bay to Matagorda Island
Houston-Dickinson	From Matagorda Island to High Island
Lake Charles, LA	From High Island to LA border

Each area is divided into the coastal waters out to 20 nautical miles and the waters from 20 to 50 nautical miles out. The NWS also makes forecasts for the rest of the Gulf (and of the Caribbean) but from forecast offices not located in Texas.

Coastal forecast data are transmitted to ocean going vessels in four ways. The Coast Guard transmits the forecast over 2640 MHz three times (instead of four) each day. NAVTEX, a teletype-like system that prints the data on special format paper copy, is used but often results in a long lag time from when the forecast is issued until it is received. The standard C-terminal satellite communication system, a part of the Maritime Safety System, is an inexpensive and faster mode of transmission. Finally the NWS provides these forecast over the NOAA Weather Radio frequencies which are widely available to coastal vessels. Figure 26 is an example of a CMF.

FZUS6 KSAT 301521
CWFSAT

COASTAL MARINE FORECAST
NATIONAL WEATHER SERVICE AUSTIN/SAN ANTONIO TX
1030 AM CDT THU APR 30 1998

TEXAS COASTAL WATERS FROM RIO GRANDE TO HIGH ISLAND OUT 50NM

NOPSIS... RIDGE OF HIGH PRESSURE OVER THE NORTHWEST GULF
WILL SHIFT EASTWARD ALLOWING ONSHORE WINDS TO RESUME TONIGHT.

GMZ150-155-170-175-302130-
COASTAL WATERS PORT MANSFIELD TO BAFFIN BAY OUT 20 NM-
COASTAL WATERS RIO GRANDE TO PORT MANSFIELD OUT 20 NM-
WATERS PORT MANSFIELD TO BAFFIN BAY 20 TO 50 NM-
WATERS RIO GRANDE TO PORT MANSFIELD 20 TO 50 NM-
1030 AM CDT THU APR 30 1998

IS AFTERNOON... NE WIND 10 KT. SEAS SUBSIDING TO 4 FT.
NIGHT... E WIND 10 KT. SEAS 3 FT.
L... SE WIND 10 KT. SEAS 3 FT.

GMZ250-255-270-275-302130-
COASTAL WATERS BAFFIN BAY TO PORT ARANSAS OUT 20 NM-
COASTAL WATERS PORT ARANSAS TO MATAGORDA SHIP CHANNEL OUT 20 NM-
WATERS BAFFIN BAY TO PORT ARANSAS 20 TO 50 NM-
WATERS PORT ARANSAS TO MATAGORDA SHIP CHANNEL 20 TO 50 NM-
1030 AM CDT THU APR 30 1998

IS AFTERNOON... VARIABLE WIND 10 KT... ELY WIND NEAR SHORE. SEAS 3
FT.
NIGHT... E WIND 10 KT. SEAS 3 FT.
L... S WIND 10 KT. SEAS 3 FT.

GMZ350-355-370-375-302130-
COASTAL WATERS FREEPORT TO HIGH ISLAND OUT 20 NM-
COASTAL WATERS MATAGORDA SHIP CHANNEL TO FREEPORT OUT 20 NM-
WATERS FREEPORT TO HIGH ISLAND 20 TO 50 NM-
WATERS MATAGORDA SHIP CHANNEL TO FREEPORT 20 TO 50 NM-
1030 AM CDT THU APR 30 1998

IS AFTERNOON... NE WIND 10 KT. SEAS 2 FT NEAR SHORE AND 4 FT
OFFSHORE.
NIGHT... E WIND 10 KT. SEAS 4 FT.
L... SW WIND 10 KT. SEAS 3 FT.

GMZ190-290-390-302130-
OUTLOOK BAFFIN BAY TO MATAGORDA SHIP CHANNEL OUT 50 NM-
OUTLOOK MATAGORDA SHIP CHANNEL TO HIGH ISLAND OUT 50 NM-
OUTLOOK RIO GRANDE TO BAFFIN BAY OUT 50 NM-
1030 AM CDT THU APR 30 1998

T THROUGH MON... AN ONSHORE FLOW WILL PREVAIL ACROSS THE TEXAS
COASTAL WATERS.

FIGURE 26. Example of a Coastal Marine Forecast.

AWIPS

The entire NWS is reorganizing to better utilize new technology. Many of these tools are effective devices for distributing pertinent information to the intended user. A newspaper article in the March 15, 1998, *Bryan-College Station Eagle*, outlines the effect that the computerization of weather forecasts has had on NWS products. The article states that improved forecasting has resulted in a significant reduction in deaths caused by severe storms. The article asserts that there were about 179 deaths per year due to severe storms, nationwide, during the 1940s. With the integration of improved forecasting and warning systems in recent years, this number has been reduced to about 40 deaths per year.

A new high-speed computer work station and communications network called the AWIPS is the centerpiece of the NWS modernization effort. The AWIPS will serve as the nerve center for operations at the 10 WFO's in Texas and the WGRFC at Fort Worth. AWIPS will be installed at several of the National Centers for Environmental Prediction (NCEP) locations including the Tropical Prediction Center (TPC), that specializes in tropical weather analysis and forecasts, and the Storm Prediction Center (SPC), that monitors and forecasts conditions that spawn severe thunderstorms and tornadoes.

The AWIPS system is composed of two primary elements—the forecast office (or components), and the communications network. The AWIPS software is capable of receiving, processing, and assisting forecasters in interactively analyzing, the weather data obtained from:

- the network of NEXRAD Doppler radars (WSR-88D);
- the next generation of GOES;
- hundreds of new ASOS;
- other data sources such as river gages; and
- forecast guidance produced at the NCEP, NHC, and the SPC.

At the sites, workstations are the main interface between weather forecasters and the AWIPS system. NWS forecasters will use the workstations to interpret and analyze data, and prepare weather forecast products for transmission. Forecasters will view large amounts of image, graphic, and alphanumeric displayed data to carry out the operational mission of the NWS. The AWIPS will store, retrieve, and display a variety of hydro meteorological data.

A communications network will feed data to each AWIPS site, distribute information among the AWIPS sites, and provide for disseminating information to the public and other outside users. Forecasters will use a one-way, point-to-multipoint satellite broadcast service, called NOAAPORT, to distribute the very large amounts of data products collected and produced at NOAA central facilities. All NES sites will have the capability to access the data distributed by NOAAPORT. Additionally, any appropriately-equipped ground station operated by private sector organizations, universities, etc., can access the data. Most importantly, the NOAAPORT system is available in text and graphic format to properly equipped planes in flight.

In addition to NOAAPORT, a high-speed data network of terrestrial communications lines interconnects the AWIPS sites. This network will allow two-way, point-to-point communications between AWIPS sites for exchanging requisite data and products that are locally collected and produced.

NOAA WEATHER RADIO

NOAA Weather Radio (NWR) provides continuous broadcasts of the latest weather information directly from the NWS. Recorded weather messages are repeated every 4-to-6 minutes and are routinely revised every 1-to-3 hours, or more frequently if needed. The broadcasts are tailored to the weather needs of users within the transmitter service area.

During severe weather, NWS forecasters interrupt the routine weather broadcasts and substitute special warning messages. They also can activate specially-designed warning receivers. These receivers either sound an alarm indicating that an emergency exists (alerting the listener to turn the receiver up to an audible volume if the receiver is being operated in a muted mode) or automatically turn on the receiver to broadcast the warning message. "Warning Alarm" receivers are especially valuable for schools, hospitals, public safety agencies, and news media offices.

NOAA Weather Radio is the sole designated government-operated radio system to provide direct warnings into private homes for both natural disasters and attack by weapons of mass destruction. The natural disasters might include earthquakes and volcanic activity. In addition, the system can provide warnings about technological hazards such as chemical or oil spills. This capability supplements warnings by sirens, commercial radio, and television.

NOAA weather broadcasts are delivered on one of seven high-band FM frequencies between 162.400 MHz and 162.550 MHz. These frequencies are not found on the average home or car radio now in use. However, a number of radio manufacturers offer special weather radios that operate on these frequencies, with and without the emergency warning alarm. Further, there are also radios on the market which offer standard AM/FM frequencies plus the so-called "weather band" as an added feature.

Specific Area Message Encoding (SAME)

A new generation of NWR receiver allows users to pre-select the NWS alerts they want to receive according to local geographic areas (counties or in some cases portions of counties). These receivers are said to have the Specific Area Message Encoding (SAME) feature, meaning the receiver is capable of turning itself on from a silent mode when the digital code is broadcast before the alarm tone is sounded for the geographical region you have preselected. Table 4.6 shows the SAME number for each county in Texas well as the frequency and call sign. A study of the Table shows that some counties cannot receive the NWS weather radio signal, but most can. There are 32 NOAA weather radio transmitters in Texas. The broadcast range of each of these transmitters is about 40 miles, depending on the height of the antenna, the terrain, the quality of the receiver and the type of receiving antenna. The limit on the transmitter range is the explanation for why the entire state is not covered. As a rule, listeners beyond this primary range

would need a very good receiver system for reliable reception. An outside directional antenna would help in these fringe areas.

Receiver prices start around \$20. Models with the warning alarm system start between \$35 and \$50. Industrial grade receivers can go as high as \$100 to \$500. Several automobile manufacturers (BMW, Mercedes, Range Rover, and Saab) equip their cars with radios capable of receiving NWR broadcasts. Several manufacturers of car radios (Audiovox, Clarion, and Panasonic) sell in-dash units capable of receiving NWR broadcasts. Manufacturers of citizen band radios with NWR channels include Cobra, Maxon, Midland, Radio Shack and Uniden.

Virtually all cities in Texas use the local fire siren as an alert for impending bad weather. These alarms have proven effective for alerting the majority of the urban public to pay attention to the weather and to take cover as appropriate.

FAA

The FAA provides a wide range of services to the aviation community. The following is a description of those FAA facilities that are involved with aviation weather and pilot services.

The primary users of weather provided by the FAA are pilots preparing for flight or en-route. Since nearly 25% of all accidents are in some way related to weather it behooves the pilot to be adept at finding and understanding the weather data available to him. Further, rapid changes in the technology and format for making weather observations and developing forecasts make it imperative that pilots stay abreast of the latest developments. These include the trend toward automation.

Flight Service Stations (FSS)

The FAA is in the process of modernizing its Flight Service Station (FSS) program with two types of FSSs. The first type is the older, manual (or non-automated) FSS that is in the process of being consolidated into the second, newer, Automated FSS (AFSS). With about one per state and with lines of communications radiating out from it, these new AFSSs are referred to as "hub" facilities.

Pilot services provided previously by the older FSSs have been consolidated into facilities with new technology to improve Pilot Weather Briefing services.

The FAA FSS or AFSS provides more aviation weather briefing service than any other government service outlet. The FSS or AFSS provides pre-flight and in-flight briefings, transcribed weather briefings, scheduled and unscheduled weather broadcasts, and furnishes weather support to flights in its area.

As a starting point for a pre-flight weather briefing, a pilot may wish to listen to one of the following three recorded weather briefings a FSS or AFSS can provide. For a more detailed briefing pilots can contact the FSS or AFSS directly.

Automated Flight Service Stations (AFSS)

In order to provide better service to more pilots the FSS has been consolidated and “automated.” The term automated refers more to the communications systems than to the weather availability, however, it does include both. Weather services provided include both pre-flight briefings and en-route updates. Typically, these are given over the telephone via the universal AFSS number (800)WX BRIEF, or over dedicated radio frequencies when en-route. The data are fed directly to the briefer’s computer by dedicated telephone line from a nearby WFO.

Information included with these pilot voice briefings include:

- adverse conditions
- VFR flight not recommended
- weather synopsis (positions and movements of lows, highs, fronts and other significant causes of weather)
- current weather
- forecast weather (en route and destination)
- forecast winds/temperatures aloft
- alternate routes (if any)
- aeronautical information (NOTAMs)
- ATC delays
- request for Pilot Reports (PIREP)

These are the elements of a *standard* briefing. *Abbreviated* briefings, usually to update an earlier briefing, and *outlook* briefings, when the departure time is more than six hours in advance of the briefing are usually somewhat less inclusive than the standard briefing.

In some instances, the pilot may request other weather information, density altitude data for example, as well as other operational information. If available, these requests are fulfilled.

Transcribed Weather Broadcast (TWEB)

The Transcribed Weather Broadcast (TWEB) is a continuous broadcast on selected low/medium frequency navigation facilities (190 to 535 kHz) and VORs (108.0 to 117.95 MHz). The TWEB is based on a route-of-flight concept with the order and content of the TWEB transcription as follows:

1. Introduction
2. Synopsis
3. Adverse Conditions
4. TWEB Route Forecasts
5. Outlook (Optional)
6. Winds Aloft
7. Radar Reports
8. Aviation Weather Observations
9. PIREP

10. Notices to Airmen (NOTAMs)
11. Military Training Activity
12. Density Altitude
13. Closing Announcement

Items 2, 3, 4, 5, and 6 are Forecasts and Advisories prepared by the NWS. The Synopsis and Route Forecasts are prepared specifically for the TWEB by WSFOs. Adverse conditions, outlooks, and winds/temperature aloft are adapted from In-Flight Advisories, Area Forecasts, and the NMC Winds/Temperature Aloft Forecasts.

TIBS

The TIBS is provided by the AFSS's to provide pilots with weather information, or other aeronautical information, that is appropriate for recording and playing over the telephone. Typically, TIBS provides area and/or route weather briefings, airspace procedures, and special announcements concerning aviation interests. Exactly when, and how, these services are provided varies with the AFSS and user demands. Usually the TIBS services offered are listed in a menu of services available to the caller at the initiation of a call to the AFSS.

HIWAS

The HIWAS is a continuous broadcast service over selected VOR's of In-Flight Weather Advisories; i.e., SIGMETs, CONVECTIVE SIGMETs, AIRMETs, Severe Weather Forecast Alerts (AWW), and Center Weather Advisories (CWA). The broadcasts are simultaneously broadcast over the entire area covered by a given ARTCC, so the HIWAS alert may be for weather some distance away from the VOR over which it is being broadcast. Figure 27 shows the HIWAS stations located in and around Texas.

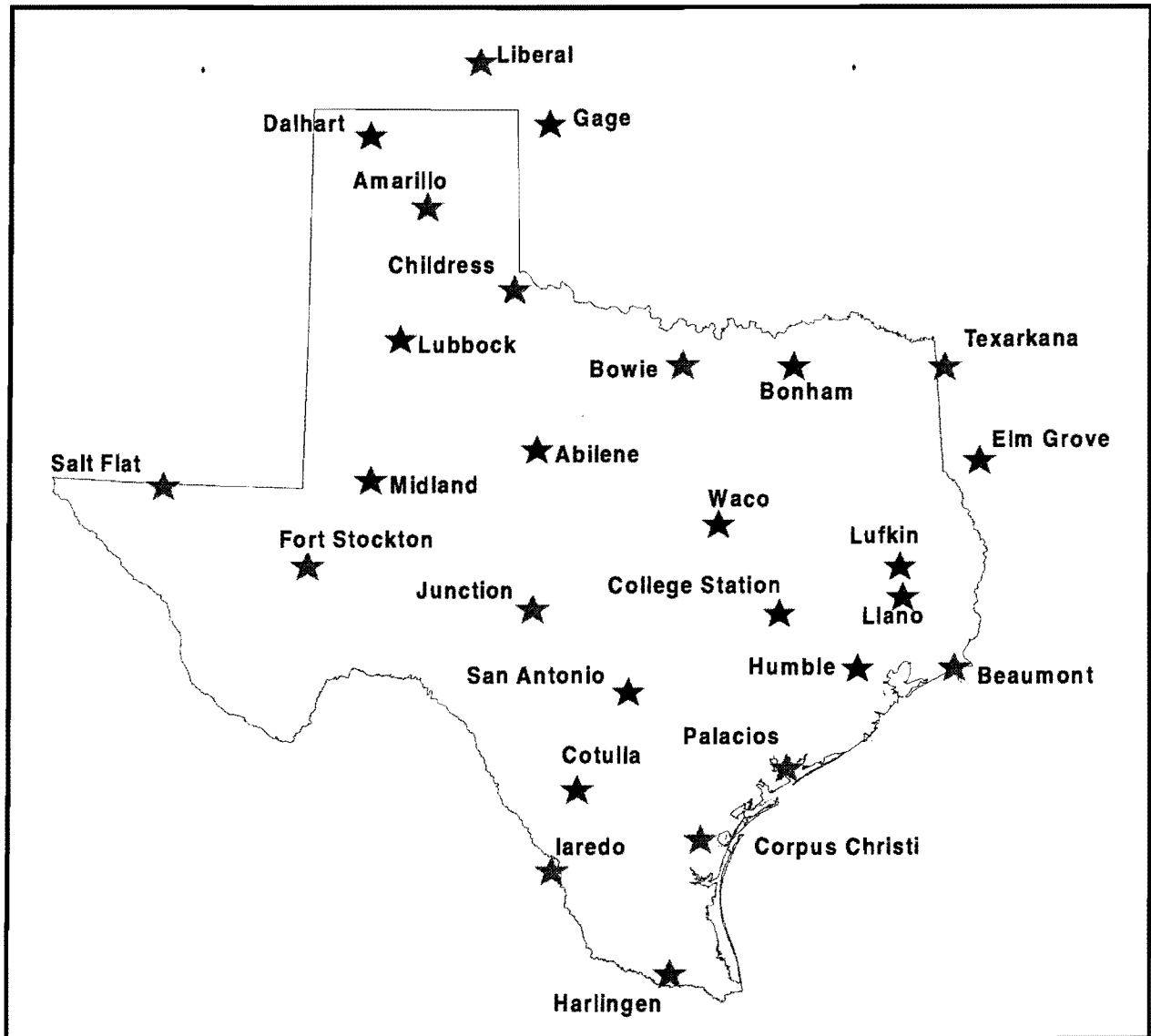


FIGURE 27. HIWAS Stations in and Around Texas.

EFAS

The EFAS, or “Flight Watch,” is a weather service on a common frequency (122.00 MHz), and on discrete frequencies at flight levels above 18,000 feet, from selected AFSSs. The Flight Watch specialist provides aviation weather information, time critical assistance for en-route pilots facing hazardous or unknown weather conditions, and may recommend alternate or diversionary routes. Additionally, Flight Watch is a focal point for rapid receipt and dissemination of pilot reports.

Figure 28 shows the FSS's and remote terminal sites of EFAS stations in and around Texas. A study of the figure indicates that there is one EFAS Control Station per ARTCC, but remote terminals are located throughout the Center area.

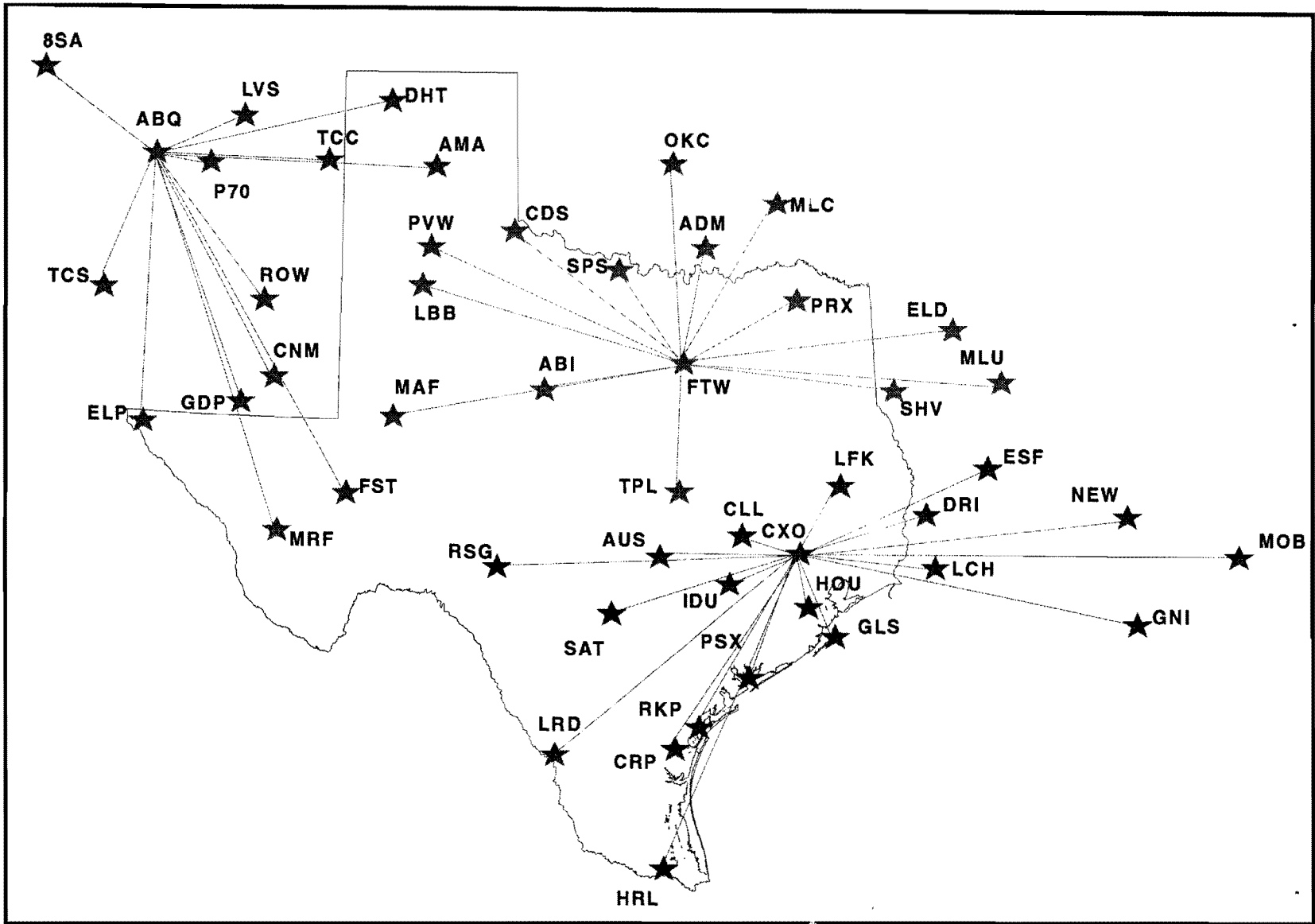


FIGURE 28. FSS and Remote Terminal EFAS Stations in and Around Texas.

Air Traffic Control System Command Center (ATCSCC)

The Air Traffic Control System Command Center (ATCSCC) is located in the Washington, D.C. area and manages the flow of air traffic on a system-wide basis. The purpose of the ATCSCC is to minimize air traffic delays by monitoring capacity and demand, thereby achieving maximum utilization of the airspace.

Because weather is the most common reason for air traffic delays and reroutings, the ATCSCC is supported full-time by NWS meteorologists in the Central Flow Weather Service Unit (CFWSU) located in the Central Flow Control Facility (CFCF). These NWS meteorologists monitor the weather throughout the Air Traffic System and anticipate weather developments that might affect system operations on the national level.

ARTCC

An ARTCC is an en-route radar facility established to provide air traffic control service to aircraft operating on IFR flight plans within controlled airspace and principally during the en-route phase of flight. When equipment capabilities and controller workload permit, certain advisory/assistance services may be provided to VFR aircraft.

Most ARTCCs have assigned NWS personnel to assist in collecting and distributing weather information as needed by the FAA controllers. These NWS meteorologists are referred to as the Center Weather Service Unit (CWSU) and furnish weather observations, forecasts, PIREPs, and suggestions to the controllers, and pilots, as needed.

Center Weather Service Unit (CWSU)

The purpose of the CWSU is to provide weather consultation and advice to managers and staff within ARTCCs and to other supported FAA facilities. The CWSU is a joint agency aviation weather support team located at each ARTCC. The unit is composed of NWS meteorologists and FAA traffic management personnel, the latter being assigned as Weather Coordinators. The CWSU meteorologist provides FAA traffic managers with accurate and timely weather information. This information is based on monitoring, analysis, and interpretation of real-time weather data at the ARTCC through the use of all available data sources. These sources include radar, satellite, PIREPs, and various NWS products such as Terminal and Area Forecasts (TAF), In-Flight Advisories, etc. The flow or exchange of weather information between the CWSU meteorologists and the FAA personnel in the ARTCC is the responsibility of the Weather Coordinator.

Similar to the CWSUs in the ARTCCs, there is a Central Flow Weather Service Unit (CFWSU) located in the CFCF in the ATCSCC. The on-duty meteorologist in the CFWSU has the responsibility of weather information coordination on the national level.

ASOS/AWOS

The NWS uses the ASOS and the AWOS to continuously make observations at sites, mainly at airports, scattered over the nation, including Texas. Observations are made continuously at these sites. However, the NWS will only poll the sensor on an hourly basis, unless significant changes in weather conditions require polling that is more frequent. Data from many of the ASOS sites are used by the NWS for reporting current weather conditions, as well as producing forecasts. Virtually all ASOS sites are accessible to the public, via telephone, and to the pilot, via a VHF radio, on a continuous basis. Pilots may also obtain the last hourly ASOS observation from a nearby flight service station.

The ASOS reports the following elements:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- basic current weather information (type and intensity);
- obstructions to vision: fog, haze;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character; and
- other data, primarily related to weather trends.

Because ASOS sensors only record these measurements at the observation point, there is some degradation of the weather data product. This is a result of the automated observation system. Deficiencies of the weather data reported by the ASOS sensors includes the inability to describe true visibility, by direction, or nearby thunderstorm(s) with the potential for lightning, gust fronts, turbulence, and hail. However, reduced costs and increased density of weather observation sites are features that out-weigh the deficiencies. Pilots can now use instrument approaches into many airports where before, without weather observers on the ground, they could not. The continuous automated observations, giving the user up-to-date weather conditions, is another valuable feature of the ASOS.

There are various types of AWOS sensors, but the AWOS-3 is the only type found in Texas. The AWOS-3 sensors report the following data:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character;
- precipitation accumulation; and
- other data as warranted, including density altitude, variable visibility, and variable wind direction.

The AWOS sensors are very similar to the ASOS sensors. The NWS also collects data from AWOS sensors for use in reporting current conditions, as well as preparing forecasts.

Figure 29 show the ASOS/AWOS locations in Texas with 30 nautical mile bandwidths around each station. These bands represent the approximate range that pilots could reasonably expect to receive the broadcast weather information while in-flight. While many regions in Texas have access to multiple ASOS/AWOS sites, many are left without any coverage from ASOS/AWOS transmissions.

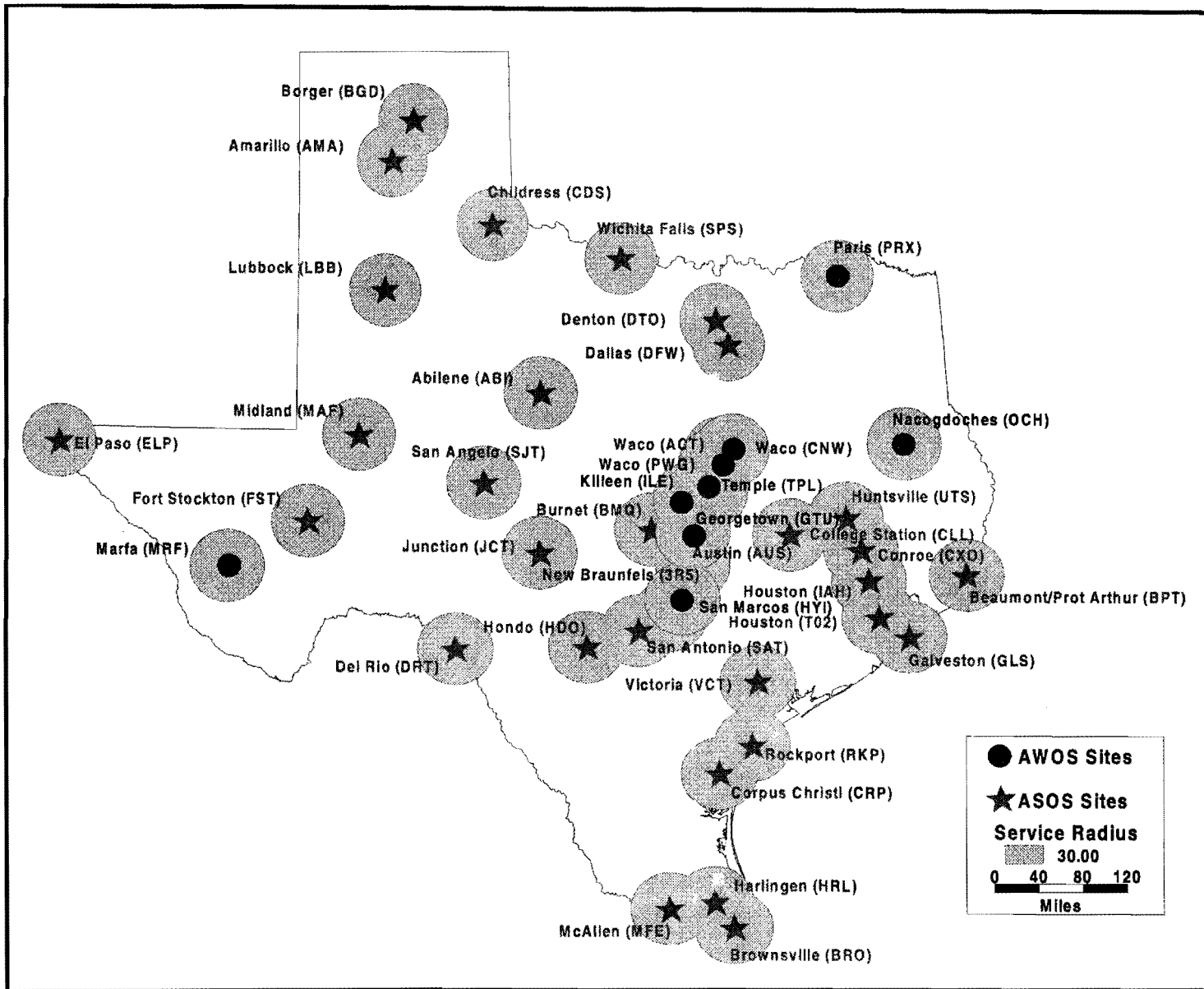


FIGURE 29. ASOS/AWOS Locations in Texas and Area of Coverage.

Automated Lightning Detection and Reporting System (ALDRS)

The Automated Lightning Detection and Reporting System (ALDARS) is designed to supplement the automated weather observations with an alert of the presence, and location, of lightning strikes within 30 nautical miles of an airport reference point (ARP). Further, the METAR will report a thunderstorm whenever lightning is detected within 10 nautical miles of the ARP.

TAFs

TAFs are only developed at NWS selected sites. The TAFs airports are shown in Figure 30. TAFs are typically issued four times each day; at 0000Z, 0600Z, 1200Z and 1800Z. Each is valid for the subsequent 24 hours. Actually for the subsequent 18 hours with the last 6 hours being termed an outlook.

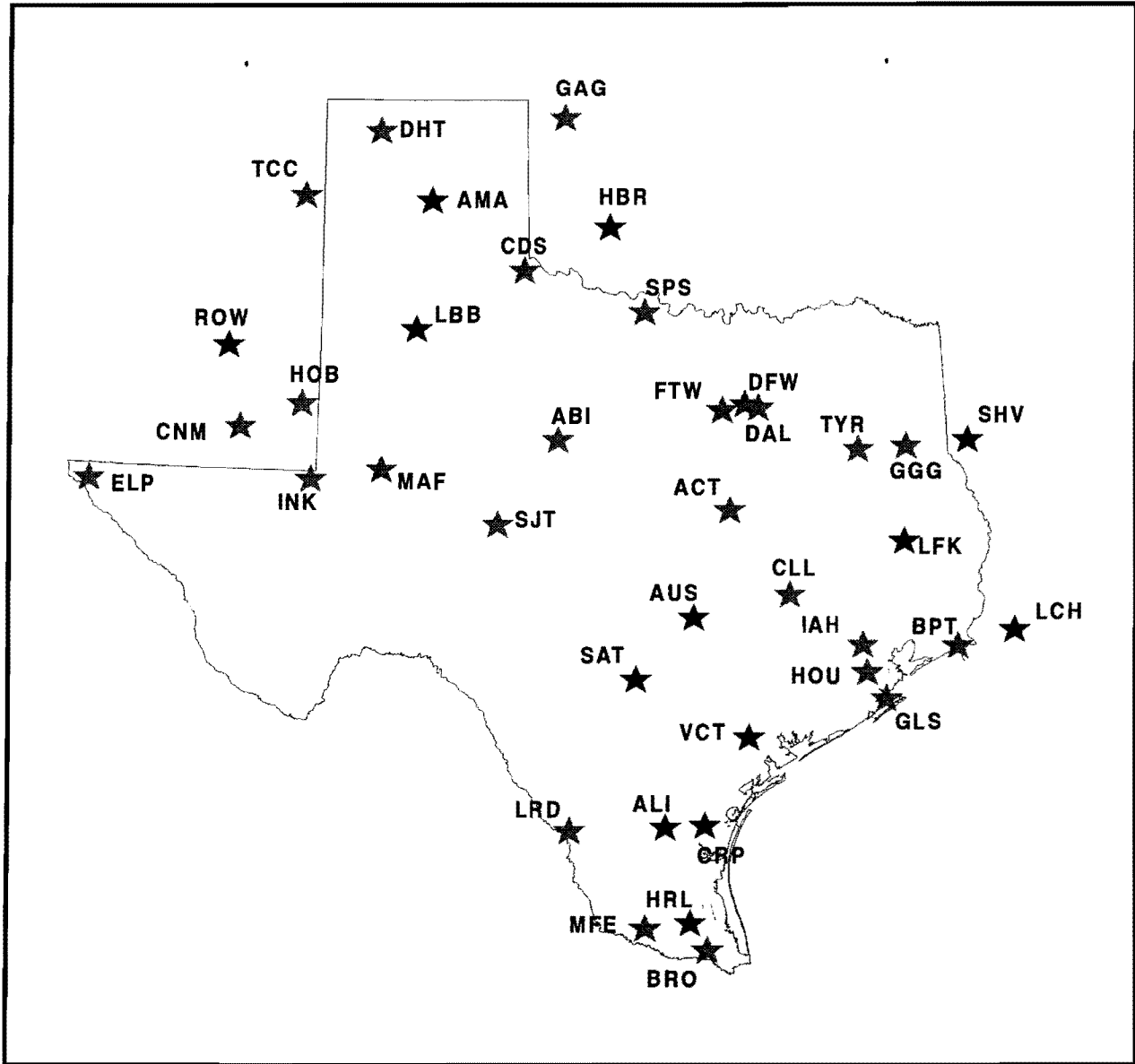


FIGURE 30. TAF Airports in and Around Texas.

AIR TRAFFIC CONTROL TOWER (ATCT)

The FAA Terminal Controller informs arriving and departing aircraft of pertinent local weather conditions. The controller becomes familiar with and remains aware of current weather information needed to perform air traffic control duties near the terminal. The responsibility for reporting visibility observations is shared with the NWS at many Air Traffic Control Tower (ATCT) facilities. At other tower facilities, the controller has the full responsibility for observing reporting and classifying aviation weather elements.

Automatic Terminal Information Service (ATIS) is provided at most major airports to inform pilots, as they approach the terminal area, of the current weather and other pertinent local airport information. Most ATIS stations make periodic recordings of the airport weather and other data pertinent to departing and arriving aircraft and broadcast it repetitively over a dedicated frequency. These data include information concerning the cloud cover, visibility, temperature, dew point, wind direction and speed, and runway in use.

Digital ATIS (D-ATIS)

Digital ATIS (D-ATIS) provides an automated process for the assembly and transmission of ATIS information. A voice synthesizer unit provides voicing for transmission over normal ATIS frequencies. Another feature of the D-ATIS is that messages can be sent to flight decks via the Aircraft Communications Addressing and Reporting System (ACARS). If the aircraft is so equipped, a visual display of the ATIS text is provided. If a printer is on board, hard copy can be produced. D-ATIS is now operational at four Texas airports—Austin, El Paso, Houston Intercontinental, and San Antonio. Other installations are planned.

TWIP

Pilots may request TWIP reports for participating airports via ACARS. The TWIP reports, available in text and character graphics format, provide information about the current weather situation for the terminal area of the selected airport. Reports may cover micro burst, wind shears, gust fronts, heavy and moderate precipitation, and location and movement of storm cells. In Texas, TWIPs are installed and operational at Dallas-Ft Worth, Houston Intercontinental, and Houston Hobby.

Integrated Terminal Weather System (ITWS)

The FAA is building and installing an Integrated Terminal Weather System (ITWS) at 34 operational sites covering 45 airports nationwide.

COMMERCIAL OUTLETS

The term “commercial outlet” includes everything that is not the government. Since the NWS makes virtually all mezo- and mega-scale forecasts, the commercial outlets simply enhance and distribute the weather in a format, or communication mode, that is more desirable, or convenient, for the user.

There is a trend toward commercial vendors playing a larger role in providing weather data collection and dissemination services in the future. A list of commercial vendors with links to their Internet home pages is located on the Internet at: <http://www.nws.noaa.gov/im/more.htm>. Several commercial vendors provide the equipment necessary to display video pictures of the weather at airports.

Direct User Access Terminal Service (DUATS)

Direct User Access Terminal System (DUATS) is an FAA operated information system that enables pilots and other aviation interests to conduct their own weather briefings. The computer-based system receives and stores a number of NWS and FAA products that are commonly used in pilot weather briefings. Pilots using a personal computer and modem can access the system and request weather and other pertinent data for planned flights. The pilot can also file and amend flight plans while dialed into the system. Further information about DUATS is available from an AFSS or FAA Flight Standards District Office (FSDO).

Only pilots with current medical certificates have access to all the features provided by this service. In addition to the weather data, these features include providing flight logs and allow pilots to encode or decode three letter identifiers.

The two vendors are:

GTE Federal Systems
15000 Conference Center Drive
Chantilly, VA 22021-3808

and

Data Transformation Corporation
108-D Greentree Road
Turnersville, NJ 08012

Knowledge of METAR and TAF formats is needed to read the textual data from these services. One option made possible by the DUATS providers is for the METAR and TAF information to be reported in standard English.

AM WEATHER

AM WEATHER is a 15-minute weather program aired Monday through Friday mornings over more than 300 Public Broadcast Television Stations. Professional meteorologists from the NWS and NESDIS provide weather information primarily for pilots enabling them to make better “go or no-go” flight decisions.

National and Regional Weather Maps along with satellite sequences, Radar Reports, Winds/Temperature Aloft Forecasts, AWWs, and In-Flight Weather Advisories are provided. Extended Forecasts are provided Monday through Friday. Friday's forecast covers the weekend. AM WEATHER also serves many other interest groups that depend upon weather information. AM WEATHER utilizes the U.S. weather observation network, GOES and NOAA Polar Orbiting satellite data, and computer analysis to produce daily aviation outlooks.

Television (Cable Weather Channel)

Of all the commercial vendors of weather information, the one seen and used the most by the public is The Weather Channel on television. In addition to being a domestic cable network operating a 24-hour all-weather format, The Weather Channel is the operator of all-weather

networks in Europe and Latin America. It also operates in more than 225 radio markets in the United States and provides customized weather packages to newspapers throughout the nation. This latter service includes the production of national and regional maps as well as local forecasts.

The Weather Channel offers special interest forecasts targeted toward viewers with specific weather needs including general aviation pilots, business travelers, gardeners, skiers, frequent flyers, private craft sailors, and cross-country drivers. Other capabilities of the service include daily earthquake updates, local emergency warnings and other technology-driven information services.

RWIS

The dissemination of the data acquired, and the forecasts that are derived, is an important component of the RWIS system. This includes:

- the transmission of data from the sensors to RPUs, from RPUs to CPUs, and from CPUs to users;
- the dissemination of road condition information to police, road users, and the traveling public;
- the acquisition of weather information by VAMS, which includes NWS-disseminated data, RWIS data, and data from other remote monitoring sources; and
- the communication of RWIS forecasts and information between forecasters (including VAMS) and users.

Meteorological data historically have been exchanged freely within the meteorological community. RWIS data, on the other hand, usually has a limited distribution because of concerns over data ownership and liability issues.

There are two distinct classes of users of RWIS type weather information. These are roadway maintenance managers and the traveling public. The maintenance managers will use the information to make decisions concerning deicing, flooding, slides and other weather related road difficulties. Travelers, of course need data about detours, potential delays, and travel restrictions caused by accidents, snow, ice, bridge closures and flash floods. An essential requirement for both classes is timeliness. Therefore, the method of communication must be accurate and timely. Two important classes of RWISs are available. These are proprietary (closed) and non-proprietary (open).

Proprietary (Closed) RWISs

A proprietary RWIS is developed and sold by a single manufacturer and contains vendor-developed software, data formats, and communication protocols for data exchange. Advantages of proprietary systems over the nonproprietary ones include the fact that as a rule they consist of proven technology, thus minimizing difficulties with maintenance and product support. Along the same line, they are easy to purchase. Off the shelf equipment is immediately available and a capability of tailoring the system to meet the needs of the buyer has usually been tried and found to work.

Disadvantages include the inability to tailor a system, using elements from other vendors, or coordinating with other existing systems. Part of these problems is simply an inability to communicate the necessary information. Another difficulty with the proprietary RWIS is providing for continuing hardware and software support if the vendor goes out of business.

Nonproprietary (Open) RWISs

A nonproprietary RWIS uses existing formats and standard communication protocols for the dissemination of information. To accommodate an interagency exchange of information the nonproprietary type equipment is preferred. However, most of the RWISs sold in this country are proprietary. The most obvious advantages of nonproprietary RWISs are that they promote competition and encourage innovation. Data exchange at all levels is feasible, a factor that may add greatly to the value of the data to forecasters and other users.

Initial cost may be the greatest disadvantage to the prospective buyer of an open RWIS system. This is because the supplier may have to make a significant development effort to gather the necessary elements of such a system. Other considerations are the liability of the owner for a systems proper performance and the additional training necessary because the field of potential users is expanded.

FOREST SERVICE (U. S. AND TEXAS)

The NWS, working with the USFS, the TFS, and the Texas Agricultural Extension Service, furnishes a weather forecast product tailored to assist in the management of the wildlands (grasslands and forests) of Texas. Management includes fire prevention and containment, as well as pest detection, growth rates, harvest schedules, schedules for the application of fertilizers and pesticides, and other management techniques (e.g., controlled burns).

The TFS has been a leader in this area. The forestry industry has an economic impact of \$8.7 billion annually while providing more than 60,000 jobs to the state. The agency, with headquarters in College Station, has fire control responsibility for 22.1 million acres of forests that average about 2,000 fires each year, burning about 40,000 acres. Interestingly, the TFS has been named the "most innovative and effective state fire control organization in the United States."

Figure 31 shows a Fire Weather Forecast issued daily by the Fort. Worth WFO. This forecast is derived from sensor data from sources furnished by other agencies, in addition to those of the NWS. All of these data are fed into the WIMS and used for developing national forecasts. National maps showing similar fire weather and fire danger components are also produced (showing, for example, live and dead fuel moisture content, drought maps, and lightning potentials).

FXUS07 KFTW 301937
 FWFFTW
 NORTH TEXAS FIRE WEATHER FORECAST
 NATIONAL WEATHER SERVICE FORT WORTH TX
 235 PM CDT THU APR 30 1998

WEATHER DISCUSSION...SKIES WILL BE CLEAR TO PARTLY CLOUDY WITH A WARMING TREND THROUGH FRIDAY.

	NORTH TEXAS	EAST TEXAS
	GRASSLANDS	FORESTS
	DECATUR/BONHAM	LUFKIN/CONROE

TONIGHT

- | | | |
|-----------------------|--------------|-----|
| 1. STATE OF WEATHER.. | CLEAR | |
| 2. PROBABILITY..... | 00 | |
| 3. WIND..... | VARIABLE 3-5 | |
| 4. MINIMUM TEMP..... | 56 | 55 |
| 5. MAXIMUM RH..... | 90 | 100 |
| 6. DEW..... | HIGH | |
| 7. FOG POTENTIAL..... | LOW | |

FRIDAY

- | | | |
|-----------------------|---------------|------|
| 1. STATE OF WEATHER.. | PARTLY CLOUDY | |
| 2. SUNSHINE HOURS.... | 9-11 | |
| 3. PROBABILITY..... | 00 | |
| 4. WIND..... | SW 5-10 | |
| 5. MAXIMUM TEMP..... | 85 | 83 |
| 6. MINIMUM RH..... | 35 | 30 |
| 7. MIXING HGT..M..... | 2300 | 1800 |
| 8. TRNSPRT WND..M/S.. | W 7 | NW 6 |

OUTLOOK

.TOMORROW NIGHT...CLEAR WITH A LOW NEAR 60.
 .SATURDAY...PARTLY CLOUDY WITH A SLIGHT CHANCE OF THUNDERSTORMS.
 HIGH IN THE 80S.
 .SUNDAY...PARTLY CLOUDY. LOW IN THE 50S GRASSLANDS AND 60S SOUTHEAST
 FORESTS. HIGH 70S GRASSLANDS AND 80S SOUTHEAST FORESTS.
 .MONDAY...PARTLY CLOUDY. LOW IN THE 50S. HIGH IN THE 80S.

NOTE

UNLESS OTHERWISE INDICATED...ENTRIES FROM LEFT TO RIGHT ON EACH
 LINE ARE FOR THE GRASSLANDS OF DECATUR/BONHAM AND THE FORESTS OF
 THE LUFKIN/CONROE AREAS. IF THERE IS ONLY ONE ENTRY...IT APPLIES
 TO ALL AREAS. FOR EXAMPLE...

MAX TEMPERATURE....	85/90	94
---------------------	-------	----

WOULD INDICATE A TEMPERATURE OF 85 AT DECATUR...90 AT BONHAM AND
 94 AT BOTH LUFKIN AND CONROE.

FIGURE 31. Example of a Fire Weather Forecast.

CHAPTER 5. POTENTIAL FOR AVIATION WEATHER

The previous chapters provided an overview of the weather data collection and dissemination system in Texas, especially the infrastructure, the personnel, and the users. New systems, such as the NWS's Advanced Weather Interactive Processing System (AWIPS), provide the tools to incorporate and use weather data provided by non-NWS sensor stations scattered around the state. Improving sensor activities and, more importantly, improving the product and its delivery to the user, is the focus of the remainder of this research.

Texas experiences a wide range of adverse weather conditions. Severe winter storms occur throughout the Panhandle, other northern areas, and in the mountainous regions. Arid areas experience dust storms, extreme heat, and droughts. Most recently, severe smoke clouds from uncontrolled range fires in Mexico and southern Texas adversely effected the state's weather. Southern and eastern parts of the state often experience heavy rain, fog, and strong winds. All parts of the state are prone to hail, flooding, lightning, and severe thunderstorms.

These weather conditions greatly impact the safety, mobility, and economics of the state's transportation system. National Transportation Safety Board records show that adverse weather conditions was a factor in over 20% of the aviation accidents in Texas. Additionally, the fatality rate was about one in four from these weather-related accidents, significantly higher than all other aviation accidents. Statistics being developed for Task 6 indicate that weather causes or contributes to more than 60 aviation-related deaths in Texas each year.

It is also clear that adverse weather greatly magnifies the risks associated with traveling, whether on the ground or in the air. More than 25% of automobile accidents in Texas occur during adverse weather conditions. Since records indicate that nearly 3,000 people are killed in motor vehicle accidents in Texas each year, 750 of these deaths are probably related to adverse weather conditions in one form or another. Surface travelers who have inadvertently driven at a high speed into a fogbank, a hailstorm, or onto an ice-glazed pavement surface understand the effects of not knowing about adverse weather conditions. The potential for saving lives by providing improved weather information is greater for surface travelers than for flying travelers.

There is also a potential for saving money and time as well. The White House Office of Science and Technology Policy (OSTP) estimates that about half of all flight delays, nationwide, are attributable to adverse weather. Additionally, uncertainties in predicting flight-level winds add \$250 million annually to the nation's aviation fuel bill. The OSTP also reports that highway maintenance agencies spend an estimated \$500 million each year preparing for winter storms that never materialize. These practices are costly to Texans, especially Texas travelers, in terms of both time and money.

GENERAL ACCOUNTING OFFICE (GAO) REPORT ON FAA WEATHER SYSTEMS

In June 1998, the General Accounting Office (GAO) released a report to Congress critical of the FAA's weather data dissemination practices to aviation users. The report specifically noted four area's of concern:

- policy and leadership;
- interagency coordination;
- meeting different users' needs for weather information; and
- level of funding provided for weather data collection and dissemination activities.

This report discussed the consequences of these concerns and detailed the safety aspects of these deficiencies.

In response to the GAO critique, FAA officials produced a table similar to Table 3. However, Table 3 includes the implementation progress of new weather systems in Texas. The GAO believes the FAA has lagged in its attention to disseminating weather data to pilots. This provides Texas aviation leaders an opportunity to influence the installation of advanced weather sensors, communication facilities, and techniques, including software and cockpit display systems.

**TABLE 3
FAA Aviation Weather Systems, Intended Users, and Implementation Schedule**

Project	Intended Users	Implementation Schedule	Implementation in Texas
Integrated Terminal Weather System (ITWS)	Controllers, terminal personnel, dispatchers	Prototypes in use; deployment scheduled for 2000-2005	In service at DFW (also at ORL and MEM)
Low Level Windshear Alert System (LLWAS) Network Expansion	Pilots and controllers	Fully deployed by 2001	
Terminal Doppler Weather Radar (TDWR)	Pilots and controllers	Currently deployed at 45 sites	In service at IAH, HOU, DAL, and DFW (also at MSY, TUL, and OKC)
New Generation Runway Visual Range (RVR)	Controllers	Deployment ongoing; currently deployed at 250 facilities	
Automated Weather Observing System/Automated Surface Observing System (AWOS/ASOS) Data Acquisition System (ADAS)	Pilots and controllers	Fully deployed in 1997	In service at both Houston and Dallas ARTCCs
Weather Systems Processor (WPS)	Controllers	Full production by 2001	Scheduled for installation at Austin Bergstrom (one currently in service at ABQ)
ASOS/AWOS	Controllers, dispatchers, meteorologists, pilots	Federal AWOS completed; ASOS fully deployed by 1999	More than 90% completed
Weather Radar and Processor (WARP)	Controllers and meteorologists	Acquisition ongoing	
Next Generation Radar (NEXRAD)	Controllers, dispatchers, meteorologists, pilots	Fully deployed; enhancements ongoing	Nearly complete
Operational and Support ability Implementation System (OASIS)	Pilots and controllers	Deployment begins in 1999	
<p>Note: In commenting on a draft of this report, the FAA requested that this table include information on several weather systems (ASOS/AWOS, WARP, NEXRAD, and OASIS) that were not included in the original list provided for our expert panel. FAA also requested that several of the existing items be amended to reflect additional users: TDWR, dispatchers, and meteorologists; and ADAS, dispatchers, meteorologists, and pilots.</p>			

IMPROVED WEATHER INFORMATION FOR AIR TRANSPORTATION

As technology continues to expand, pilots and aircraft users are demanding, and receiving, improved weather reports and forecasts. Through improved capabilities for flight planning and severe weather avoidance, short-term forecasts of adverse conditions—such as icing, turbulence, thunderstorms, micorbursts, and windshears—will significantly enhance flight safety. These improved forecasts offer the potential for increasing system throughput more cost-effectively than constructing new airports, new runways, or other alternatives. Other benefits include reduced aviation fuel consumption, shorter weather induced delays, and lower deicing costs for airports.

The largest technical obstacles to the expanding technologies involve the existing communications and dissemination systems. The lack of graphical weather products, adequate ground-to-air communications, and cockpit displays results in weather products that deliver too much data and not enough real information. These limitations not only prevent the dissemination of improved weather forecasts, but also limit the distribution of valuable weather information about current conditions. This is primarily a communications system problem. Although the FAA is capable of creating graphical representations of weather information, it lacks the communications capability to disseminate this data, particularly to the pilot in the air or on demand from the pilot in the air. The following sections present several technologies and practices and their potential application in Texas.

Satellite Image Enhancements

The National Oceanic and Atmospheric Administration (NOAA) has several satellites in orbit that observe the migrations and intensities of weather phenomena. Each new generation of satellite increases the capabilities of the data collection system and its sensitivity to the atmospheric data being measured. These satellites are helping meteorologists develop long range and seasonal forecasts, and they determine local parameters such as rain rates, snow depth, and sea surface winds.

Currently, NOAA has two geo-synchronous spacecraft, GOES-8 and GOES-9 that provide wide-area stationary views of the eastern Atlantic Ocean and the eastern Pacific Ocean. These views include the eastern and western U.S. Additionally, two polar satellites, NOAA-12 and NOAA-14 (telstar 401), provide closer views of smaller areas to supplement the data from the GOES. During May 1998, the first of a new generation of satellites, the NOAA-15 (Galaxy 4), was launched into a sun-synchronous polar orbit. The satellite orbits the earth every 102 minutes at an altitude of about 516 miles. Typical fields of view from these satellites are as depicted in Figure 32. Images from these satellites are available to the NWS and the FAA for use by pilots and others.

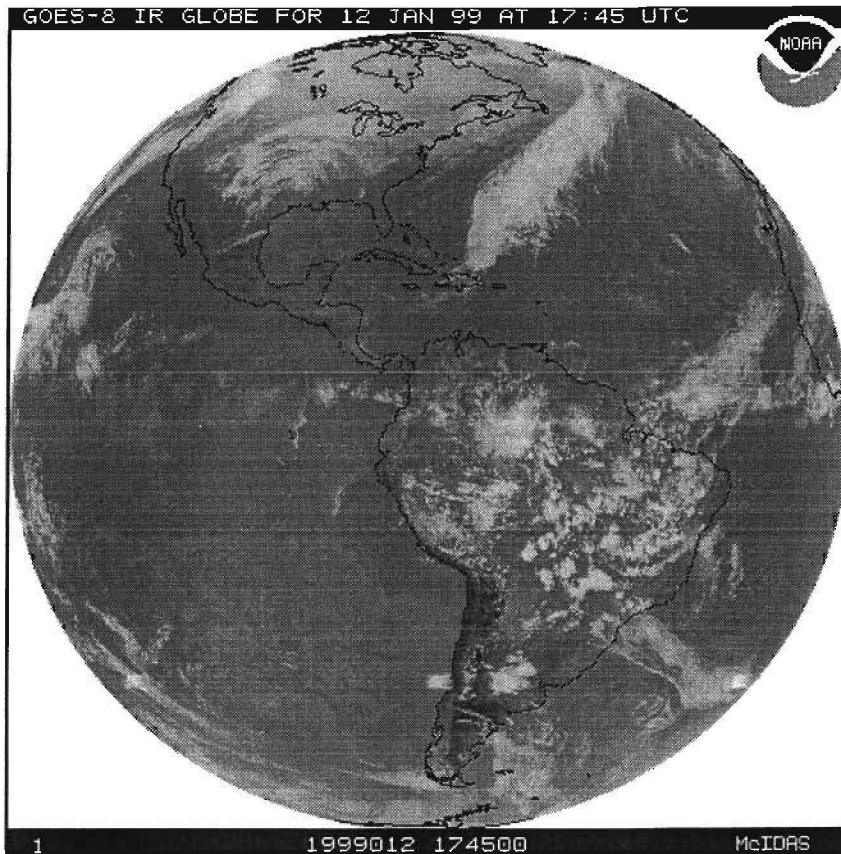


FIGURE 32. Fields of View from Weather Satellites Currently in Orbit.

Unfortunately, the proper use and significance of the images is not readily apparent. Their enhancement, by providing more localized views, superposing other pertinent data, and educating potential users are relatively inexpensive value-adding services that would help pilots better understand weather conditions expected en-route. Figure 33 depicts weather conditions observed at airports superposed on a GOES 8 visible satellite image. Figure 34 is a more localized satellite image, in this instance, the southeast U.S. The image in Figure 34 has the capability of being looped, i.e., it can move with time over the past several hours.

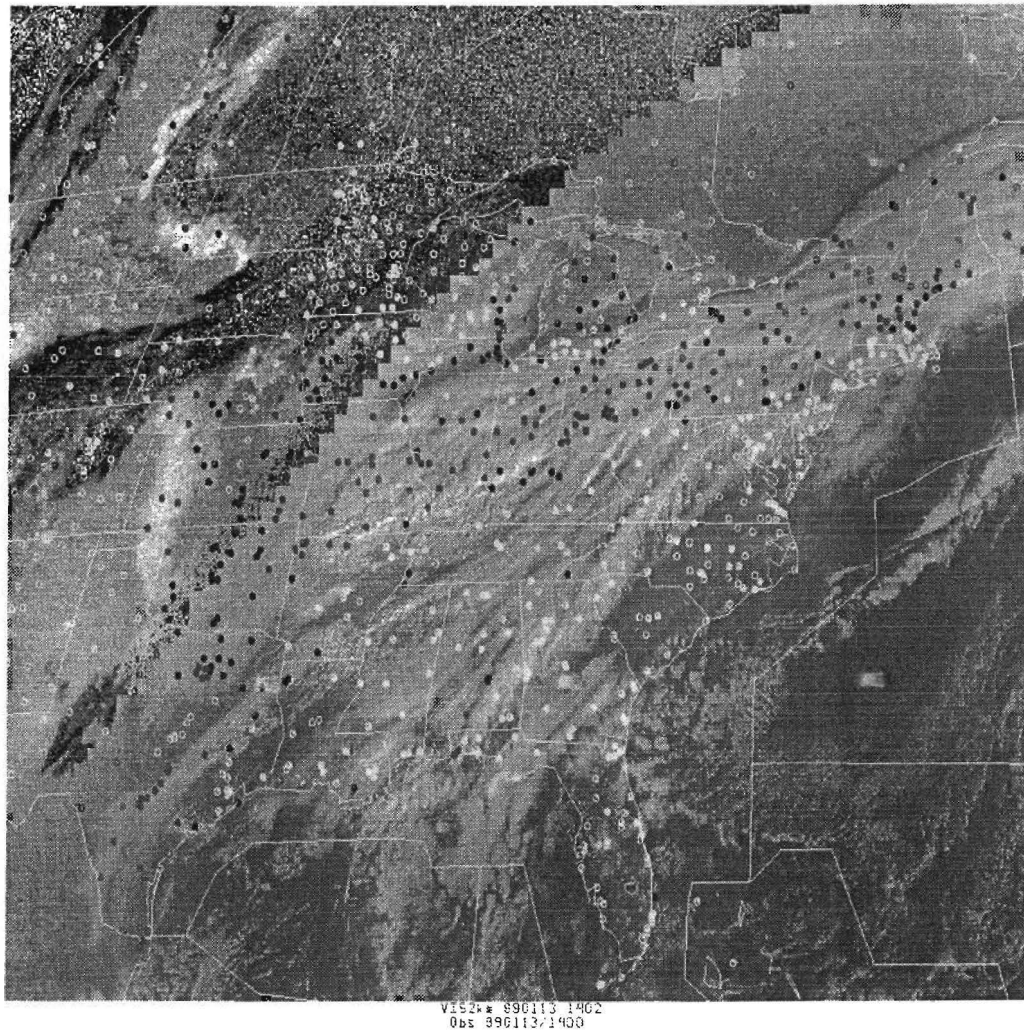


FIGURE 33. Airport Weather Observation Superposed on the GOES 8 Visible Satellite Image of the Eastern U.S.

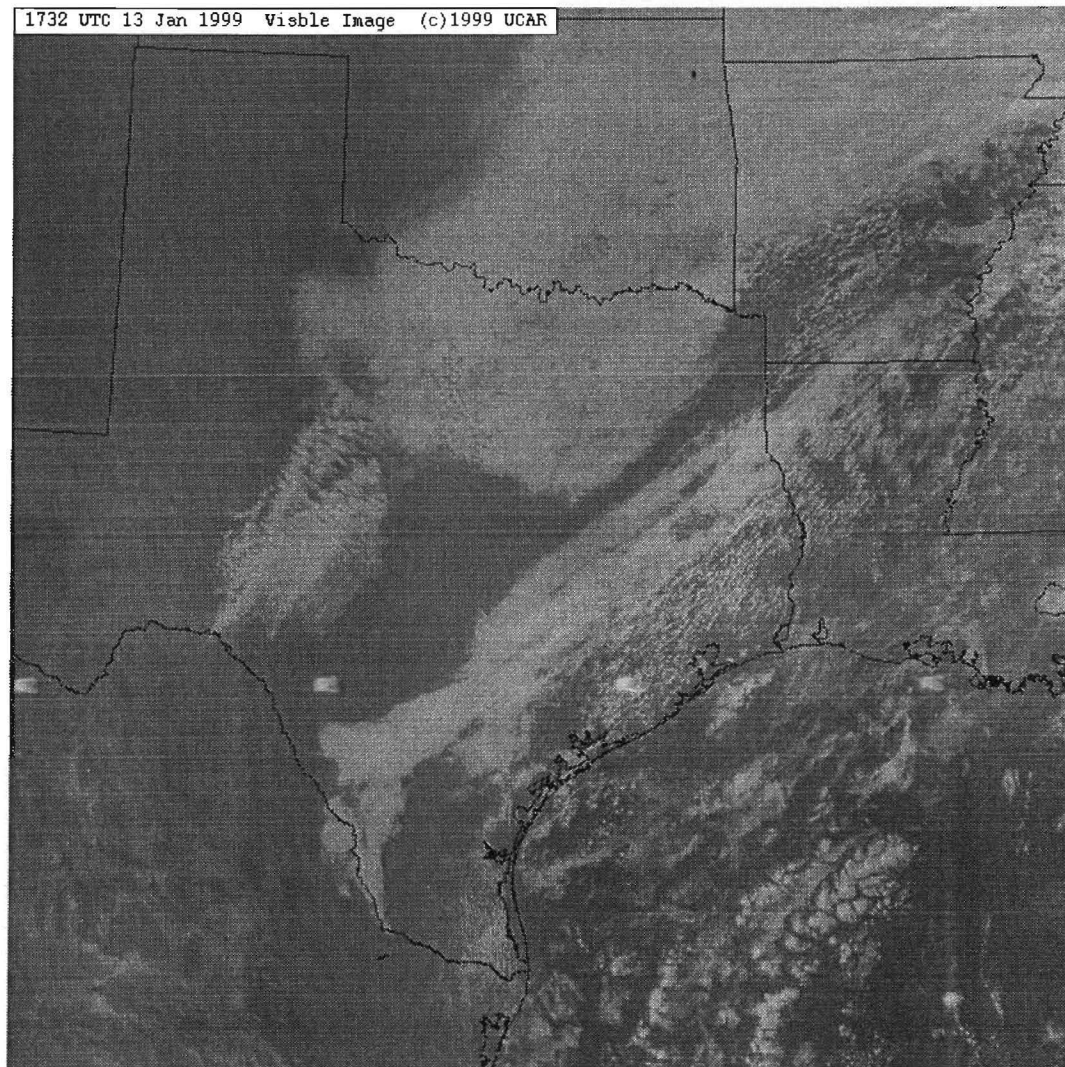


FIGURE 34. Satellite Image Over a Localized Geographical Area.

Icing Forecasts

Since publishing its “In-Flight Aircraft Icing Plan,” in April 1997, the FAA has expended a large amount of research time and effort to better understand and forecast dangerous airframe icing, especially super-cooled-large-droplets. One approach showing promise is the “observation-based stovepipe algorithm.” In this approach, surface observations are combined with temperature and humidity conditions aloft to define areas, and altitudes, where icing is anticipated. The nickname “stovepipe” refers to the vertical column of air that the algorithm considers.

A similar algorithm to develop icing forecasts is predicated on forecast surface and aloft conditions. Several computer software and technical advancements have made this possible. One is an artificial intelligence tool used for pattern recognition and is called a neural network. Another is the ability to process changing conditions in three dimensions and in shorter time increments. These improved capabilities at the NWS are leading to more detailed, more reliable, and more frequent forecasts for all users, especially pilots. This is especially true for airframe icing forecasts.

Meteorologists at the National Center for Atmospheric Research (NCAR) in Boulder, CO, are spearheading the implementation of these new technologies. It is anticipated the new technologies will lead to more reliable airframe icing predictions so pilots are assured that when icing is predicted, pilots will experience icing, and when it is not predicted, pilots will not experience icing.

Figure 35 is a textual AIRMET announcement, the current approach to alerting pilots about the potential for icing. It originated at the Aviation Weather Center (AWC) in Kansas City, MO. Figure 36 shows the area defined in the AIRMET announcement where airborne icing is expected. The plot eliminates the need to decode the identifiers defining the extent of the expected icing. Figure 37 shows the web page that links to the experimental imagery maps developed by the NOAA. In this figure, the map links are highlighted. These maps show the conditions conducive to airborne structural ice formation. Figure 38 shows contours, using a neural network devised by the AWC in Kansas City, describing the potential for developing airborne structural icing. The contour values range from zero to five, with five having the greatest potential for icing.

NCEP/AWC - Chicago Airmet Zulu - Icing and Freezing Levels

13 Jan 1999 - 15:40:24 UTC

Please read disclaimer for information regarding the availability and timeliness of forecasts and products.

ZCZC MKCWA3Z

WAUS1 KCHI 131540 AAA

CHIZ WA 131540 AMD

AIRMET ZULU UPDT 5 FOR ICE AND FRZLVL VALID UNTIL 132100

.
AIRMET ICE...KS MO OK AR...UPDT

FROM PWE TO COU TO LIT TO OKC TO PWE

OCNL MOD RIME ICGIC BLW 050. CONDS ENDG AFT 21Z.

.
AIRMET ICE...MO WI LM MI IL IN KY AR TN

FROM MKE TO DTW TO FWA TO CVG TO HNN TO 40W BKW TO LIT TO COU TO MKE

OCNL MOD MXD/RIME ICGICIP BLW 140 N OF FAM-IND LN AND BTN 080 AND FL180 S OF FAM-IND LN. CONDS SPRDG SEWD AND CONTG SWD BYD 21Z THRU 03Z.

.
AIRMET ICE...ND SD NE MN IA

FROM YDR TO MSP TO PWE TO VTN TO 80SW DIK TO 50NNW ISN TO YDR

OCNL MOD RIME/MXD ICGICIP BTN 040 AND 120. CONDS SPRDG SEWD ACRS AREA AND CONTG BYD 21Z THRU 03Z.

.
AIRMET ICE...NE KS

FROM VTN TO PWE TO GCK TO 80W GCK TO 60W LBF TO 60SSW BFF TO VTN

OCNL MOD RIME ICGIC BTN 080 AND 160. CONDS DVLPG AND MOVG SWD CONTG BYD 21Z THRU 03Z.

.
FRZLVL...SE OF FAM-CVG LN...070-090.

W OF MLS-VTN-GAG LN...MULT FRZLVLS SFC-050 BECMG 030-050 BY 21Z.

RMNDR...AT OR NR SFC.

.....=

NNNN

FIGURE 35. Textural Announcement of the Potential of Picking Up Ice.

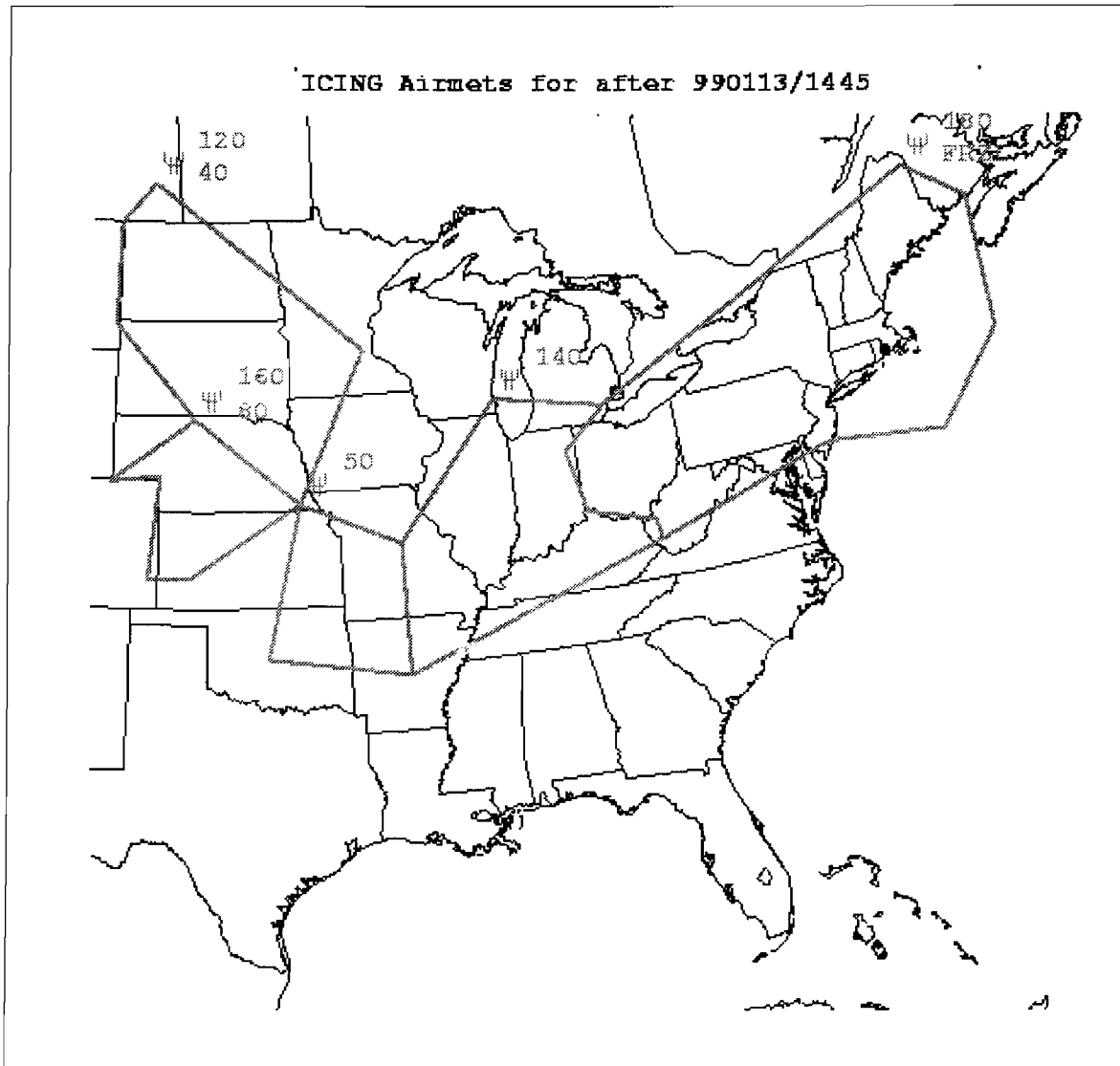


FIGURE 36. Geographical Area Defined by the AIRMET Message in Figure 35.

Aviation Weather *dot* Com. Icing Forecast Page

How To Read These Icing Maps.

When viewing icing maps you will see color contours with numbers of the same color. These numbers can range from 1 though 6. 1 represents the lowest chance of icing and 6 the highest.

We have spoke with Don Mc Cann @ NOAA/ AWC and he reminds us this is a experiential system. We are told that there will be a newer icing forecast available in the next few months. We will post the new (improved) program as soon as it is available.

Thank you weather Site Inc. 305-669-0007

This is experimental output. The Experimental Forecast Facility at the Aviation Weather Center is evaluating the output to see if there are any flaws. Anyone using this product as a flight-briefing aid should always consult the latest Aviation Weather Center icing advisories

Initial Analysis	Forecast for 1800 UTC	Forecast for 2100 UTC	forecast for 0000 UTC	Forecast for 0300 UTC
Flight Level 0 feet to 6000 feet	Flight Level 0 feet to 6000 feet	Flight Level 0 feet to 6000 feet	Flight Level 0 feet to 6000 feet	Flight Level 0 feet to 6000 feet
Flight Level 6000 feet to 14000 feet	Flight Level 6000 feet to 14000 feet	Flight Level 6000 feet to 14000 feet	Flight Level 6000 feet to 14000 feet	Flight Level 6000 feet to 14000 feet
Flight Level 14000 feet to 30000 feet	Flight Level 14000 feet to 30000 feet	Flight Level 14000 feet to 30000 feet	Flight Level 14000 feet to 30000 feet	Flight Level 14000 feet to 30000 feet
Flight Level 0 feet to 30000 feet	Flight Level 0 feet to 30000 feet	Flight Level 0 feet to 30000 feet	Flight Level 0 feet to 30000 feet	Flight Level 0 feet to 30000 feet

Data distribution via the Internet is not considered an operational delivery mechanism by the NWS due to their inability to insure access to this service, therefore, the information available here shall not be used for flight planning or other operational purposes.

FIGURE 37. The NOAA Experimental Display with Links to Maps Showing Areas Where Parameters Are Conducive to Airborne Icing.

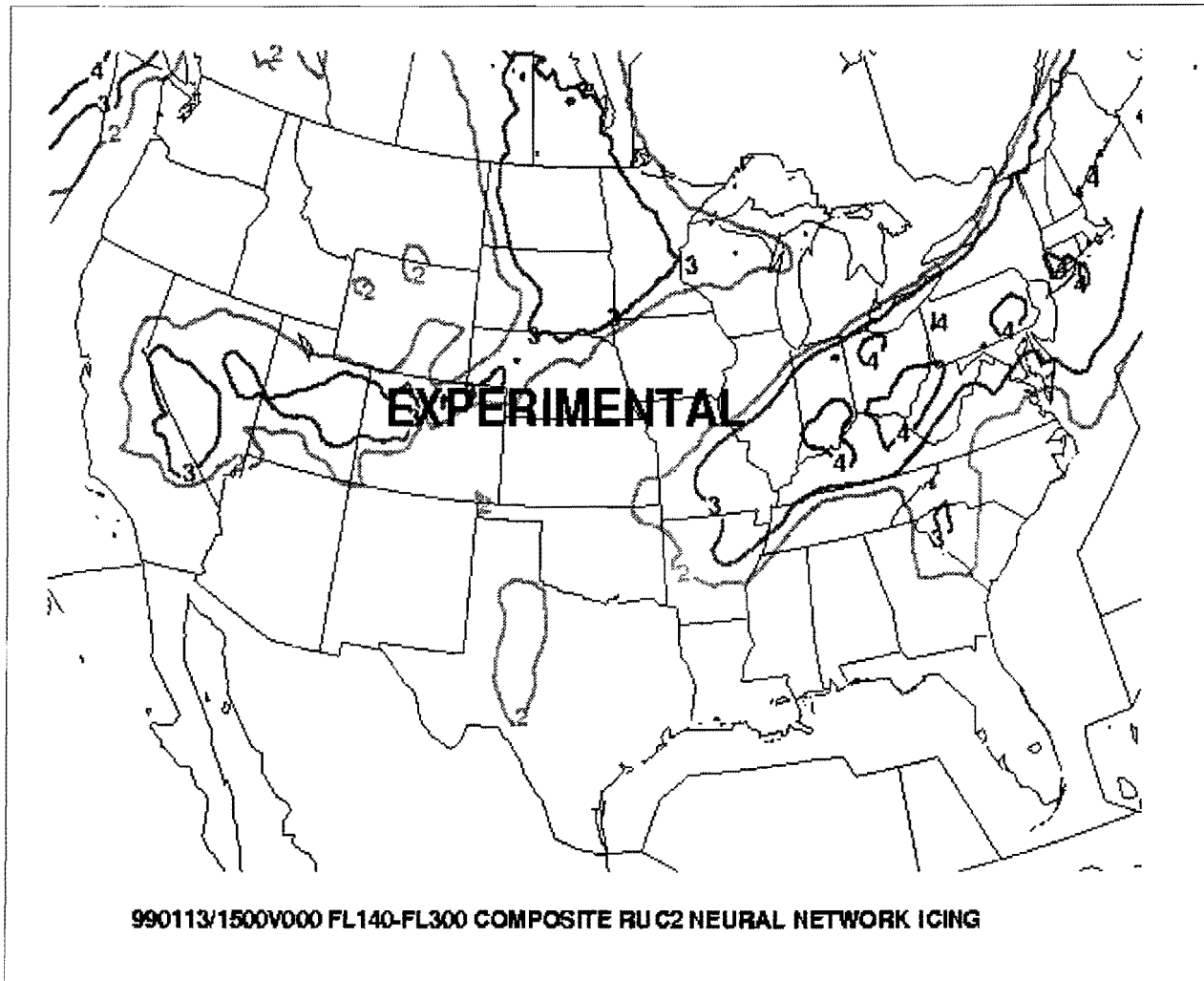


FIGURE 38. Contours Showing the FAA's Neural Network Approach to the Potential for Airborne Icing. (Contours Applying to Altitudes of 6,000 Through 14,000 Feet.)

Access to ASOS and AWOS Data

Iowa has instituted a weather data collection network called the Iowa Aviation Weather System (IAWS). Information from the AWOS sites in Texas is available to all pilots in the state as a computer-synthesized voice report via local telephone numbers. Several of the reporting locations are also accessible from personal computers. The personal computer must have a communication program and a Hayes-compatible modem.

ASOS sensors, mainly at airports, are scattered over the nation, including Texas. Observations are made continuously at ASOS sites. However, the NWS will only poll the sensor on an hourly basis, unless significant changes in weather conditions require polling that is more frequent. Data from many of the ASOS sites are used by the NEWS for reporting current weather

conditions, as well as producing forecasts. Virtually all ASOS sites are accessible to the public, via telephone, and to the pilot, via a VHF radio, on a continuous basis. Pilots may also obtain the last hourly ASOS observation from a nearby flight service station.

The ASOS reports the following elements:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- basic current weather information (type and intensity);
- obstructions to vision: fog, haze;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character; and
- other data, primarily related to weather trends.

Because ASOS sensors only record these measurements at the observation point, there is some degradation of the weather data product. This is a result of the automated observation system. Deficiencies of the weather data reported by the ASOS sensors includes the inability to describe true visibility, by direction, or nearby thunderstorm(s) with the potential for lightning, gust fronts, turbulence, and hail. However, reduced costs and increased density of weather observation sites are features that out-weigh the deficiencies.

There are various types of AWOS sensors, but the AWOS-3 is the only type found in Texas. The AWOS-3 sensors report the following data:

- sky condition: cloud height and coverage up to 12,000 feet AGL;
- visibility up to 10 statute miles;
- pressure: sea level pressure and altimeter setting;
- ambient temperature and dew point temperature;
- wind direction, speed and character;
- precipitation accumulation; and
- other data as warranted, including density altitude, variable visibility, and variable wind direction.

The AWOS sensors are very similar to the ASOS sensors. The NWS also collects data from AWOS sensors for use in reporting current conditions, as well as preparing forecasts.

Texas could make a comparable system available to pilots and other users in the state via an 800 number. This would provide valuable information to pilots whether they access the synthesized voice or the computerized data.

“Free Flight” Forecast

The capability of several new navigation systems, permitting point-to-point navigation, puts additional pressure on weather data providers to present and forecast conditions along specific routes and at various altitudes. Additionally, when weather conditions dictate deviations from the planned route, the detour must be specified, mutually understood by the pilot and controller, and both will require weather conditions and forecasts along the new route. Graphical representations of this data would benefit both the pilot and the controller.

Textural Displays in the Cockpit

One of the major concerns raised by the GAO about implementing new technology to provide pilots with up-to-date weather information was that the pilot is receiving too much data and not enough information. Much of the weather data is delivered orally rather than through graphical displays or printed textural displays that pilots could study and review.

Automatic Advisories

At uncontrolled airports near airports with radar, Texas could consider integrating a system that produces a voice-synthesized radio advisory of airplanes observed near the airport. (See *Aviation Week and Space Technology*, June 30, 1997, p 38.) This service is in addition to the current weather conditions being transmitted now.

The Lincoln Laboratories at the Massachusetts Institute of Technology developed and demonstrated a traffic alert system for uncontrolled airports. However, this “poor-boys” traffic alert and collision avoidance system relies heavily on using a Mode S transponder. Unfortunately, installation of Mode S transponders in most general aviation airplanes is on the decline.

DUATS Graphic Localized

DUATS is an FAA operated information system that enables pilots and other aviation interest to conduct their own weather briefings. The computer-based system receives and stores a number of NWS and FAA products that are commonly used in pilot weather briefings. Pilots using a personal computer and modem can access the system and request weather and other pertinent data for planning flights. The pilot can also file and amend flight plans while dialed into the system.

A number of private vendors provide this weather information graphically to pilots and other users. To improve this service, vendors could provide weather graphics on a higher scale chart showing Texas and adjacent states. Instead of receiving graphics that show the entire U.S., pilots could obtain weather depictions on a more localized map. Using applets to denote prominent landmarks, i.e., cities and roads, will add greater value to the weather depictions.

Only pilots with current medical certificates have access to all the features provided by the DUATS service. In addition to the weather data, these features include providing flight logs and allow pilots to encode or decode three letter identifiers.

Mesoscale Weather

The information presented above shows that a more refined, in both time and space, presentation of weather conditions and forecasts are needed. The NWS is addressing this problem through model programs called the Mesoscale Analysis and Prediction System (MAPS) and the Rapid Updated Cycle (RUC). The MAPS program proposes to provide data assimilation and forecasts on a 40-km grid with a vertical spacing of 25-mb (about 1,000-ft) of pressure change. The RUC implies updating forecasts every hour as opposed to the traditional three-hour analysis.

One important capability that the new software, such as the AWIPS and Local Data Acquisition and Dissemination System (LDADS), gives the NWS and FAA is the ability to incorporate data from the myriad of small, often specialized, weather sensors scattered across the state.

Weather Education

The rapid development of new sensors and new dissemination methods make it difficult for the typical user to keep pace with the most efficient methods to collect and use weather data. The Air Safety Foundation (ASF), a branch of the Aircraft Owners and Pilot Association (AOPA), instituted a program to educate pilots about new methods for obtaining pre-flight weather information.

A grant from the Florida Department of Transportation, matched dollar-for-dollar by the ASF, resulted in a series of seminars entitled, "Weather Strategies" being presented in 15 Florida cities. While most pilots still rely on the telephone briefing for their primary weather information, the ASF seminar provides pilots information on integrating information from various sources. These include The Weather Channel on television, local TV Doppler radar, AOPA ONLINE, Internet weather services, DTN and other equipment at FBO's, and the FAA's DUAT system. The seminar also teaches pilots how to evaluate information from AWOS and ASOS automated weather reporting systems.

These seminars and classes are helpful and almost mandatory as technologies for disseminating weather information rapidly change.

IMPROVED WEATHER INFORMATION FOR SURFACE TRANSPORTATION

Several state Departments of Transportation are attempting to collect and efficiently use weather data. Typically, they are using off-the-shelf weather sensors primarily designed to help maintenance personnel determine whether conditions dictate immediate corrective action. This usually involves snow or ice removal.

These self contained sensors, commonly called RWIS, typically consist of the actual sensors and three other identifiable components: the RPU, a CPU, and the communications link between two units. The RPU is located at the sensing site and the CPU is usually located at the district headquarters, where it collects, analyzes, and distributes the data and forecasts from the sensors. TxDOT has approximately 15 RWIS sites in service in three districts.

Following is a discussion of other programs and practices used in the U.S. for disseminating weather information for surface transportation.

Warnings of Local Weather Hazards

Modeling the FAA's Flight Service Station, a system that uses an 800 telephone number to provide pilots with weather conditions, Texas could implement a system to provide weather information to drivers also using an 800 number. Typically, this system would provide information about the following weather safety considerations:

- ice on bridge;
- ice on road;
- high water on road;
- fog on road;
- blowing sand on road;
- blowing snow on road;
- hail;
- high wind; and
- heavy rain or sleet.

These safety considerations are often location specific, depending upon the density of the sensors and the capability of the forecaster, and are capable of being delivered via the telephone, including through recorded messages.

Weather Information by Facsimile or E-mail (or Net)

The State of Colorado collects data from as many as 88 weather stations installed around the state, plus information from the NOAA, the Colorado State Patrol, and verbal reports from others, and disseminates this data by facsimile. Colorado provides facsimile reports several times a day, automatically, to a list of user agencies. These include freight hauling companies, ports of entry, visitor centers, ski areas, radio stations, and television networks. The reports are issued more frequently in the winter than in the summer. Generally, the reports are sent to subscribers who pay for the service.

Texas could consider implementing this type of system and the reports could be sent upon demand by non-regular subscribers. Additionally, it is possible to provide the same data via E-mail or telephone.

Traveler Information Via the Internet

Both Iowa and Illinois have web sites on the Internet tailored to the needs of travelers visiting specific locations. The following are examples of the type of information included in these pages:

- local area maps;
- tourist attractions;
- parking availability; and
- tourist amenities.

When appropriate, the web site also provides information about adverse weather conditions. The Internet is a convenient method to distribute specific and timely information, and, with time, the population of users is rapidly growing.

TxDOT has a web site, <http://www.dot.state.tx.us/hcr/main.htm>, where it disseminates information about road construction activities. Users visiting the site can find out if road lanes are closed on a particular route or if other construction activities are impeding traffic flow.

Speed Warning System

A speed warning system involves a radar sign that flashes back the driver's speed and, when applicable, suggests a slower speed based on weather conditions ahead. For example, the radar sign may flash, "You are going 61 mph, 35 mph is better for icy road ahead." These warning signs are relatively inexpensive and are mounted on trailers. This configuration allows crews to reposition the system as weather conditions dictate.

Several states respond to adverse weather by reducing speed limits on roads. Nevada changes its speed limits when ice forms on roads and Utah and Georgia reduce speed limits when visibility is diminished due to fog.

NOAA Weather Radio

Conventional AM-FM radios are easily and economically equipped with a third band covering the seven frequencies dedicated to NOAA weather broadcasts. Several top-of-the-line automobiles are currently sold with the third band as a standard feature. This permits the driver to retrieve routine weather reports en-route. When special warning messages are appropriate, the routine weather reports are interrupted with the special warning.

This broadcast service is currently available to 70% to 80% of the U.S. population. About the same percentage of Texans have access to this service. In coastal areas, the NOAA Weather Radio transmits weather condition reports appropriate for the needs of seagoing vessels, recreational sailors, the Coast Guard, as well as others.

Mobile Weather Sensors

This concept involves the installation of inside reference (IR) pavement surface sensors on vehicles to detect surfaces that might require anti-icing treatment. This program is more effective in areas where fixed RWIS installations are not present. In areas where there is an established RWIS system, the remote, moving sensor could assist in identifying pavement requiring early treatment.

Manage Bad Weather (Snow) Routing

This program would have limited application in Texas, as most areas, except the Panhandle and north Texas, do not experience heavy snowstorms. Areas experiencing sandstorms, fog, and flash flooding from heavy precipitation may have use for a similar program.

Weather Information Via Telephone

During the April 29, 1998, broadcast of ABC's program entitled "Prime Time Live," a report suggested that cellular telephones could alert people about the possibility of tornadoes or other life threatening weather. The report stated that this alert system is already in widespread use in Europe. The report implied that the Federal Communications Commission (FCC) specifically declined to pursue this system adding that this use of cellular telephones was not in the FCC's legislative charter.

The report stated that as of the date of the broadcast, April 29, 1998, 109 people had been killed during the year by tornadoes in the U.S. The report suggested that since the consequences of adverse weather are so severe, private telephone companies should provide this service themselves.

Another inexpensive possibility is to provide weather forecasts, especially severe weather forecasts, to travelers via an 800 telephone number. This system would mirror the (800) WX-BRIEF number currently used only by aviation. It would include a TIBS-type recording clearly identifying that the weather information is appropriate for surface travelers.

Weather Information From Commercial Data Providers

This potential weather information service consists of a video screen and chart presentation of radar- and satellite-based observations and forecasts. The system would have the capability of printing textural descriptions of the observed and forecast weather. Possible locations for these systems are roadside park kiosks or travel information offices.

Weather Information Superposed on Moving Map

If navigation systems assist drivers in locating address in an unfamiliar area, it is equally feasible to mark areas of adverse weather on the same map. This weather-mapping system is envisioned to use data links with satellites. The moving map is linked to a GPS satellite and stored memory indicates the driver's position in relation to towns, highways, streets, states, and other physical features, both natural and man-made. Through a data link, the driver can request weather information for display on the LDC. For example, the system could display current Doppler weather radar images referenced to the vehicle's position. Additionally, the system could display text messages from the NWS.

RESEARCH BY DEPARTMENTS OF TRANSPORTATION

Advanced Transportation Weather Information System (ATWIS)

The Advanced Transportation Weather Information System (ATWIS) is a consortium of government agencies working to demonstrate the efficacy of mesoscale meteorological analysis and forecasting for highway users and maintenance personnel. While the intent of the program is to become fee-supported and conducted primarily at the University of North Dakota, the applications should benefit highway users in both North Dakota and South Dakota.

The ATWIS project is designed to provide short-range weather and road condition forecasts to travelers and commercial vehicle operators. The forecasts cover 3,200 miles of roadway across the two states (Figure 39).

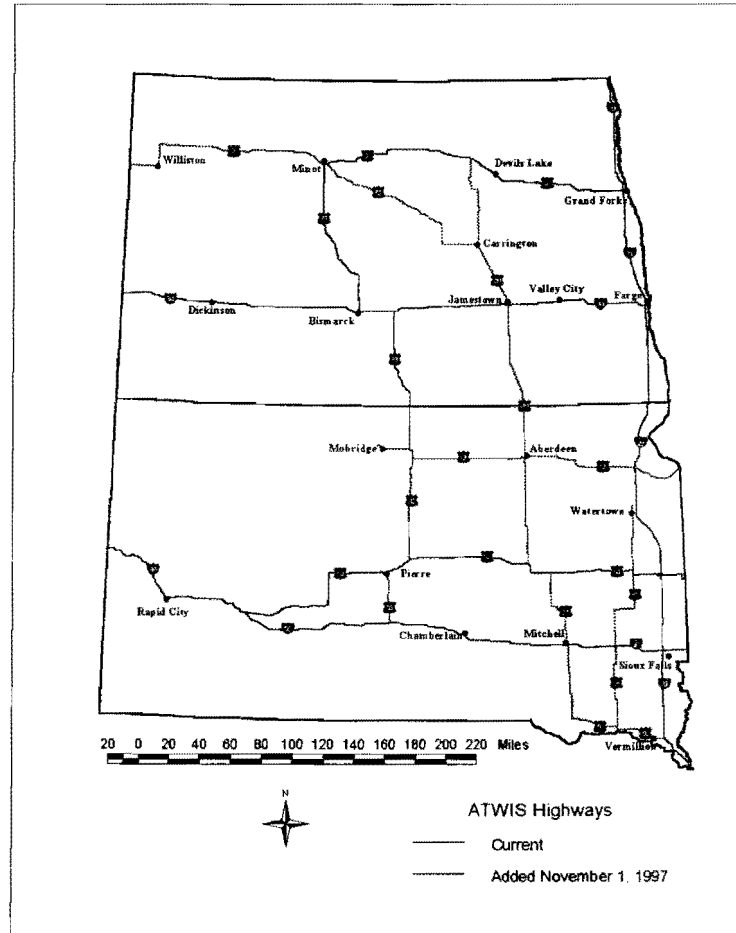


FIGURE 39. Map of North and South Dakota Showing the Highways Covered by the ATWIS Project.

Typically a cellular telephone user dials #7233 (#SAFE) along any of the highway test areas shown in the figure. The caller must then answer a few questions concerning their location and direction of travel. The computer then constructs an envelope around the caller's vehicle, extending 60 to 80 miles (one to two hours of travel time) ahead in the direction of travel. Through interactive voice technologies, the caller receives a weather and road condition report for the road segment. The telephone call takes an average of one to one-and-a-half minutes.

FORETELL

FORETELL is a consortium of five state Departments of Transportation and the Ontario Ministry of Transport. The program is using Intelligent Weather Systems (IWS) and Intelligent Transportation Systems (ITS) to collect and disseminate weather data to travelers, shippers, and transportation system operators across North America. The states involved in the program include Iowa, Illinois, Minnesota, Missouri, and Wisconsin. Motivation for the program appears to have come from a lawsuit where the Ontario Ministry of Transport lost \$2.2 million for improperly maintaining a highway. The lawsuit alleged that the road surface was allowed to ice over and a serious car crash resulted.

The FORETELL program is designed to collect all the data available, including NWS and FAA observations and forecasts, and use this data to predict weather and roadway conditions. The program is testing more than one privately owned software package to provide local and precise predictions for travelers and roadway maintenance workers. The Local Data Acquisition and Dissemination feature of the AWIPS software of the NWS is expected to be an important component of the program.

Users of the products generated in this program include:

- State DOT Maintenance Personnel
- Quasi-Public Agencies
 - Hospitals/Ambulances
 - School Districts/School Bus Operators
 - Public Safety Agencies
 - Emergency Management Agencies
 - Travelers and Freight Shippers
 - Cellular 'Push'
 - Premium Rate Call-in Service
 - Radio and TV
 - Internet 'Push'
 - Internet Web Pages

The product generated in this program can include warnings about pavement icing, thunderstorms, lightning, hail, hazardous winds, drifting snow, reductions of visibility, and high water conditions.

The Texas MesoNet Plan

To provide more precise weather forecasts and improve weather observation capabilities across the state, a team of meteorologists at Texas A&M University and elsewhere have suggested forming a denser geographically spaced system of weather sensors. This system is called the Texas MesoNet system of weather observing sites. The project will add a number of sensors to the state system and improve coverage in areas where the current distribution of sensors is sparse. The system is similar to the current system operating in Oklahoma. Figure 40 shows the planned

MesoNet system and Figure 41 shows a “proof-of-concept” plan currently used to demonstrate the practicality and need for the MesoNet.

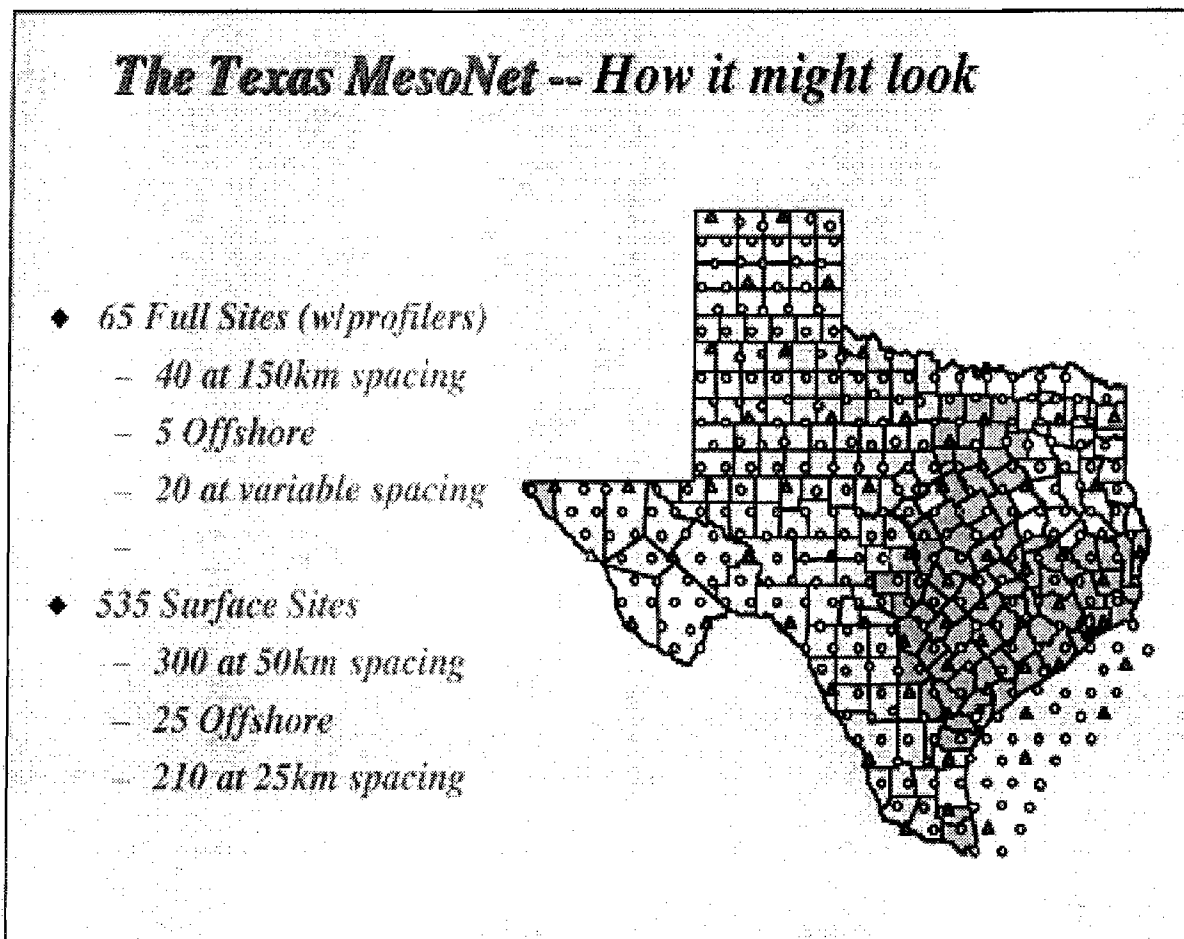


FIGURE 40. The Planned Texas MesoNet System.

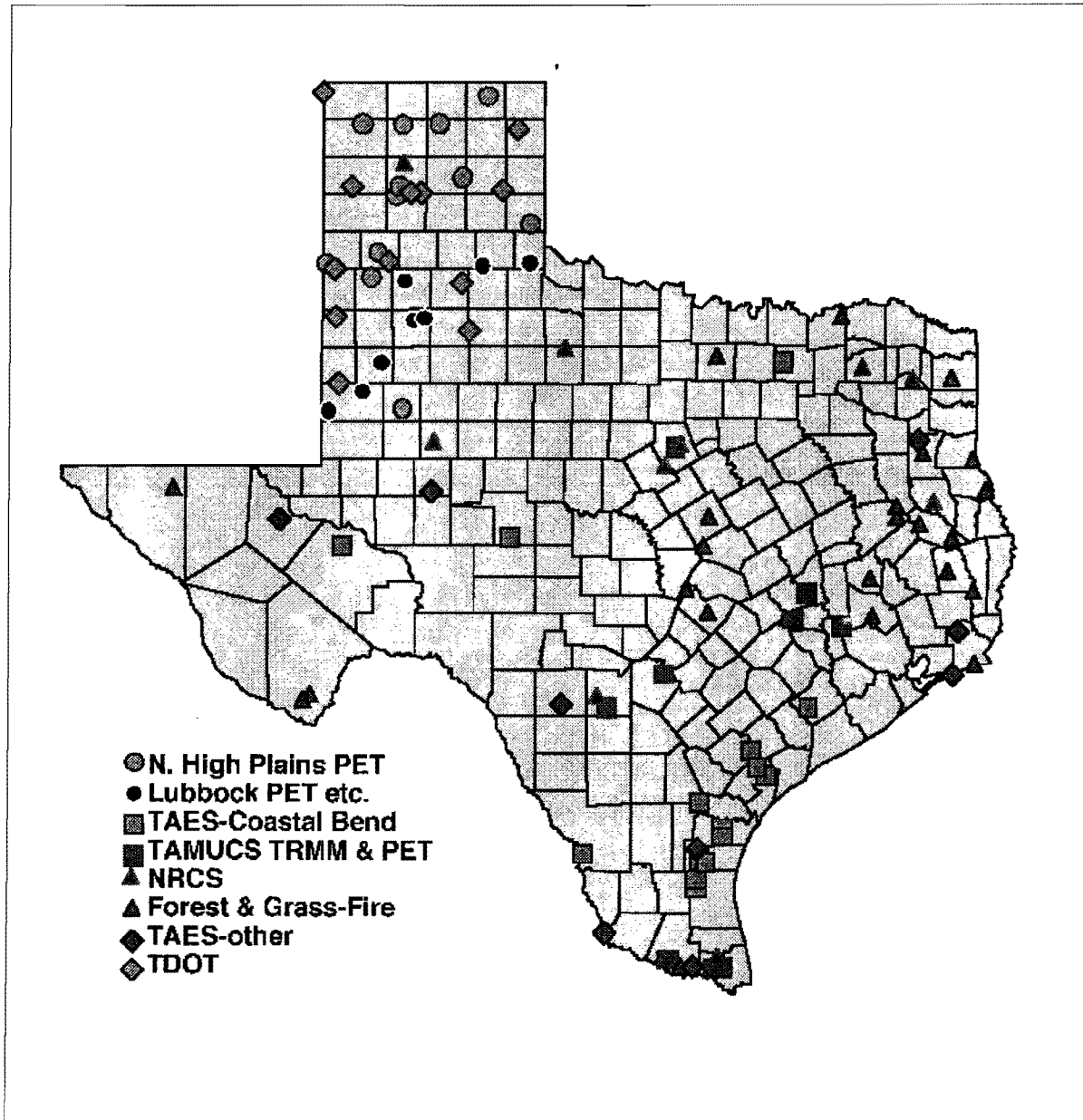


FIGURE 41. Proof-of-Concept Version of the Texas MesoNet System.

Sensors at each proposed MesoNet site would record the following measurements:

- wind speed and direction at 10 meters every 15 minutes;
- air temperature and relative humidity at 1.5 meters every 15 minutes;
- barometric pressure every 15 minutes;
- precipitation every 15 minutes; and
- solar radiation every 15 minutes.

Supplemental measurements every 15 minutes for the proposed inland and coastal sites includes:

- wind speed at two meters;
- air temperature at nine meters;
- soil temperature at various depths;
- leaf wetness;
- pan evaporation; and
- soil moisture at various depths.

Supplemental measurements for the other sites includes:

- sea surface temperature;
- wave height;
- current speed and direction;
- salinity; and
- tide.

Highway and airport transportation managers in Texas are increasingly using weather sensor technology to assist with winter maintenance operations. The current extent of sensor deployment is patchy, and a fully integrated road-weather information system is not operational. The main reasons for this situation are the relatively high system costs, reliance on general meteorological forecasts rather than obtaining highway-specific information, and the need to interpret environmental data. Other reasons include a lack of meteorological skills among maintenance supervisors, incompatibility between manufacturers' systems, performance and coverage restrictions with current sensor technology, and the lack of coordination between state and municipal agencies and forecasting services. Still other reasons include the resistance to automate existing procedures, a lack of knowledge of state-of-the-art systems, and a low rate of occurrence of adverse winter weather conditions. One last, but not least, point is the state's reluctance to expose itself to further liabilities.

As it is presently configured, the Texas MesoNet plan fails to use state-of-the-art sensors to collect data on atmosphere variables that are important to air transportation. These variables include cloud cover and height, visibility, barometric pressure, and nearby lightning strikes.

A concept being pioneered by the State of Missouri is to co-locate the ASOS (for aviation use) and RWIS (for highway maintenance use) sensors and provide the resulting data to both local and NWS clients. There is the potential to adopt this concept in Texas and include the Texas MesoNet. There are several sites where ASOS units currently exist eliminating the need for MesoNet sensors if arrangements were made to provide the collected data to the MesoNet users.

More importantly, there are several sites where ASOS sensors currently do not exist, but are needed. This is where planners intend to establish a MesoNet site. The advantages of using joint sites are lower costs, site location for observing weather, and communicating data to a central

processing point. Sharing sites allows for disseminating useful information to highway maintenance personnel, airport maintenance personnel, and other specialized weather data users in Texas.

One possibility for disseminating MesoNet observations is through an Internet web site, similar to the FAA's ASOS web site. The web site would make data available to surface travelers and other users, including pilots. An ideal format for this information is TxDOT's web site that provides information on road construction activities. This would provide users with information on both road construction and weather delays at one source.

If the data is transmitted in the METAR format, it is necessary to provide the same training pilots receive so users can read and understand the data. One solution is to develop a system of modifying the METAR reports, developing the information into reports that more directly meet the needs of all drivers.

There are other applications where MesoNet data is useful. They include:

- military applications;
- forecast validation;
- agriculture;
- commercial fishing;
- outdoor activities;
- environment and air quality; and
- forensic applications.

Military Applications

Calculating the flight path of artillery and ballistic missiles relies on knowledge of the direction and magnitude of the winds aloft. Accurate forecasts of winds developed from MesoNet data is especially important to the troops at Fort Hood and Fort Bliss as was as troops at White Sands, NM, Fort Still, OK, and Fort Polk, LA.

Forecast Validation

Validating forecasts and establishing climatological archives is the most important role of the Texas MesoNet. Calibrating the time-intensity integration of NEXRAD radar to establish and record overall rainfall is especially important.

Agriculture

The use of aircraft for spraying pesticides, distributing fertilizers, and sowing seeds is common in many parts of Texas. Virtually every application requires specific weather conditions. Pilots need accurate flight visibility to find the field, monitor coverage, and avoid obstacles. Pesticides must not blow onto a neighbor's crops or foliage. The ASOS sensor is more valuable in this application than the MesoNet sensor described in Figure 40.

Commercial Fishing

Offshore sensors are an integral part of the Texas MesoNet system, and combined with satellite observations, will allow fishermen to pinpoint areas in the Gulf of Mexico that are conducive to productive fishing. Particularly, the sensors and satellite observations will help fishermen determine where there is an abundance of plankton.

Outdoor Activities

Improved weather information and forecasting will enhance the enjoyment of outdoor activities, primarily recreational activities. Enhanced forecasts and other data will help people decide whether or not to take an umbrella to a football game, help them decide whether or not to play golf or stay home, or help them determine if conditions are conducive to fishing. Additionally, improved weather data is an important factor in safety and health considerations.

Environment and Air Quality

During the spring of 1998, range fires in Mexico and south Texas produced heavy smoke and smog layers that blew and hovered over Texas and other southern states. Because of the high concentration of small particulates in the air, and their unusual tendency to linger, the Texas Natural Resource Conservation Commission (TNRCC) issued a Public Health Alert. The reproduced alert (Figure 42) indicates that it was disseminated via the Internet, NOAA weather radio, local television stations, local radio stations, and the cable television service provider.

**FOR IMMEDIATE RELEASE
WEDNESDAY, JUNE 3, 1998**

**CONTACT: PATRICK CRIMMINS
512/239-5000 (Pager 512/606-3026)**

Satellite Images

General Report on Particulate Matter

STATE RE-ISSUES SMOKE PUBLIC HEALTH ALERT
Smoke Expected First in South Texas, Along Gulf Coast

The smoke-related public health alert has been re-issued for the entire state, effective at midnight Wednesday, June 3, and continues until conditions warrant its cancellation. The alert has been re-issued by the Texas Natural Resource Conservation Commission (TNRCC) and the Texas Department of Health.

Satellite images on Wednesday showed a large area of smoke from the fires in Mexico south-southeast of Brownsville moving to the north. Smoke is expected to begin to effect large portions of South Texas by late Wednesday, and by Thursday and Friday could affect portions of central and east Texas.

Fine particulate matter in the smoke has the potential to exceed federal air quality standards, which is the basis for re-issuance of the alert.

The TNRCC and the Texas Department of Health would like to remind Texas residents that:

- People in the affected areas with respiratory conditions and heart disease, and the elderly, should avoid exertion and outdoor activity. Because the particles are so small, physical exertion should be avoided even if indoors by this group.
- Everyone else, especially children, should consider avoiding prolonged physical exertion, even indoors, and consider avoiding outdoor activity.

"The re-issuance of this alert is precautionary measure," said TNRCC Chairman Barry McBee. "It is difficult to know with any precision how thick the smoke will be when it gets to Texas, and what areas will be most effected. We continue to urge Texans to pay close attention to local conditions because this continues to be a very dangerous situation."

A toll-free information hotline set up by the TNRCC, 1-800-687-4040, is still operating with recorded information and will be updated several times daily.

All TNRCC news releases are available at www.tnrcc.state.tx.us/exec/media/press/

-30-

FIGURE 42. TNRCC Public Health Alert.

Houston Regional Monitoring is a consortium of Houston industries that monitors and records weather and atmospheric environmental data at seven locations in the Houston-Galveston area. One of the sites, operated under contract by Radian International, is shown in Figure 43. This site, in east Houston near the ship channel, continuously monitors the PM2.5 (the size of solid particulate matter in the air with a characteristic dimension of 2.5 microns or less). These monitoring sites provided the TNRCC the necessary information to issue the health alert. The monitoring site shown in Figure 43 also includes equipment to measure meteorological variables.

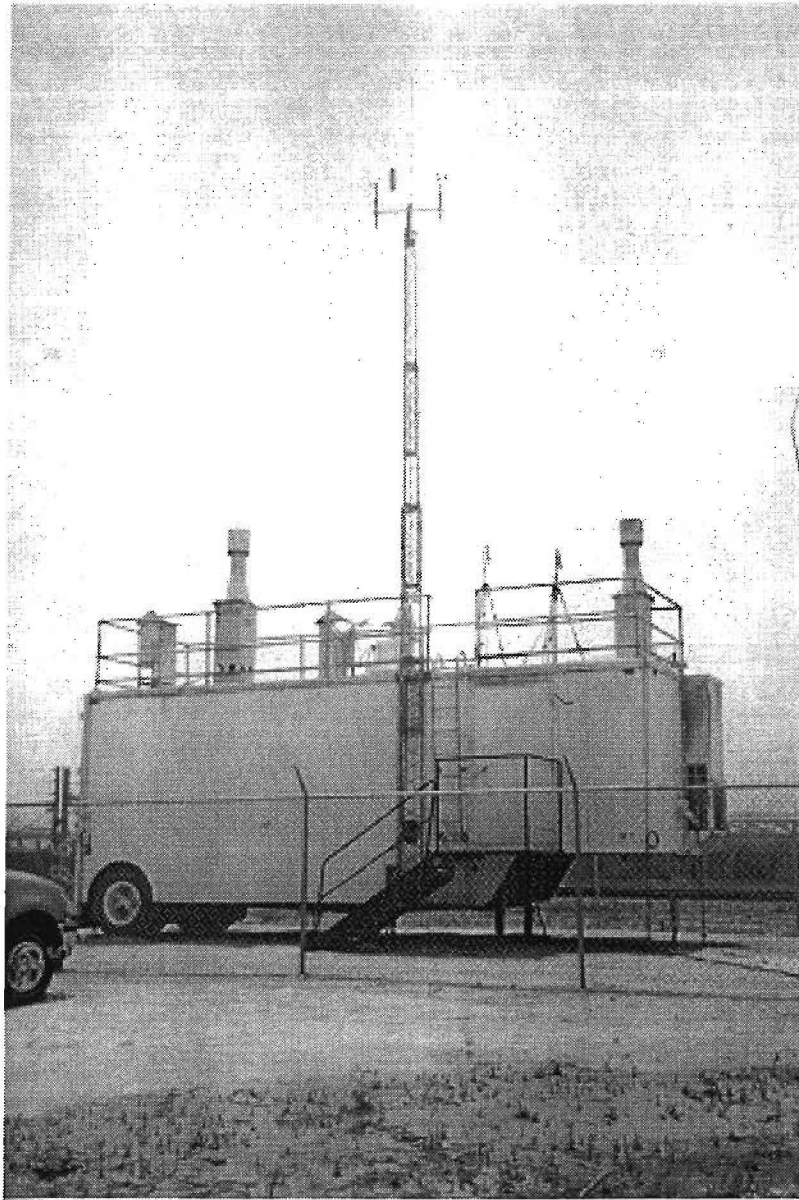


FIGURE 43. Photograph of the Particulate Monitoring (PM2.5) Site Near the Houston Ship Channel.

The TNRCC expects to install other similar stations across the state in the near future. Figure 44 shows possible locations for the PM_{2.5} sensors.

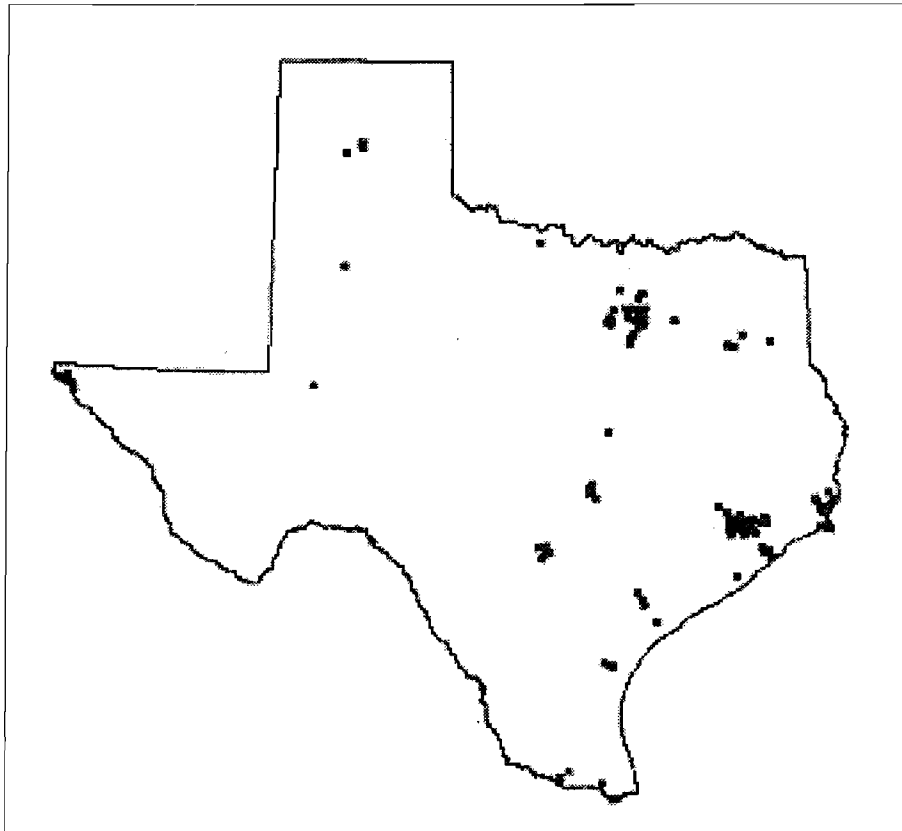


FIGURE 44. Possible Locations for PM_{2.5} Sensors in Texas.

Forensic Applications

Weather records are also useful in forensic application. Local weather is often critical in after-the-fact lawsuits involving construction or environmental disputes.

An interesting example involves an October 1987 snowstorm in eastern New York State. The heavy snow on trees still laden with leaves caused many tree limbs to break, hit power lines, and disrupt electrical power services. One disgruntled customer sued the Niagara Mohawk Power Company for food spoilage since his refrigerator was inoperable during the prolonged power outage. He alleged that he had relied on Niagara's early prognosis that power would be restored within two days after the storm ended.

The counsel for the utility employed a meteorologist to review the data "available" and to use it to establish the culpability of the company. Records indicated that the storm of October 3 - 4,

1987, was not consistent with the historical climatology of the area, was truly an act-of-God and could not have reasonably been foreseen by the power utility. The judge ruled that while Niagara Mohawk's forecast was incorrect, the forecast was made in good faith and the power utility was not liable for the customer's food spoilage.

CHAPTER 6. DATA COLLECTION AND CODING

Weather-related accident data from the NTSB were extracted, interpreted, and reorganized. Specifically, the NTSB web page was used to access summaries of aircraft accident reports to identify accidents in which weather was a probable cause or contributing factor, the number of fatal accidents, and the number of fatalities from each accident. Summaries of final accident reports were examined for all aviation accidents and incidents that occurred in Texas during the period January 1983 - December 1996. The NTSB data were used to create a separate data file for subsequent manipulation and analysis.

NTSB accident synopses from January 1983 - June 1998, by month, are found at <http://www.ntsb.gov/aviation/months.htm>. Preliminary reports still exist for most accidents which occurred after December 1996. Weather-related accidents which occurred in Texas were selected by searching the NTSB database for accidents with the month and state of interest. The search results produced a brief description of the location, aircraft type, and number of fatalities for each accident.

Individual accident summaries were reviewed, and the data were entered into a database file. Records for each accident contained the year, month, and day of the accident; and the aircraft registration number. The records also included the number of fatalities due to the accident; the flight phase during which the accident occurred; the attributed weather-related cause (if any); and up to three contributing, weather-related factors. Accidents involving commercial aircraft were separately identified.

Aggregate comparisons of summary statistics were made between Texas and national data, as appropriate. Nationwide summary statistics were recorded separately. National data include all accidents investigated by NTSB from all locations and for all causes. These were entered into a spreadsheet file, separate from the Texas accident database. National accidents rates were obtained from the FAA Office of System Safety, Aviation System Indicators.

DATA LIMITATIONS

There are limitations in the NTSB accident summary data, which include a lack of information about pilots' certifications, ratings, flight experience, and flight plans. No trend analysis was performed for Texas accident data, since there were no comparable measures of total aircraft operations available. However, monthly national rates and 12-month average national rates of general aviation accidents were obtained from FAA. A trend analysis was performed for these data.

An additional limitation of the national NTSB data is that commercial accidents (including some that occurred outside the 50 States) are mixed with general aviation accidents. The NTSB database does not readily allow searches that include the 50 States but exclude accidents outside the States. Where this may influence the interpretation of results, adjustments or possible impacts were noted. Commercial aviation accidents that occurred in Texas were identified.

ANALYSIS OF WEATHER-RELATED ACCIDENT DATA

Weather-related accident data from January 1983 through December 1996 have been analyzed and are summarized below. Several basic comparisons are made, followed by a more detailed discussion and analysis.

Texas Versus the Nation

Table 4 shows total accidents nationwide and in Texas, by fatality category. Note that this comparison includes commercial aviation accidents as well as general aviation accidents, and that it includes all accident causes (weather-related or non weather-related). Table 4 also shows that Texas accounted for approximately 6.5% of all aviation accidents and 7.2% of all fatal aviation accidents during 1983 - 1996. In Texas, the ratio of fatal accidents to total accidents was 18.2%, for the 1983 - 1996 period. Nationally, the ratio was somewhat lower: 16.6%.

TABLE 4
Summary of Aircraft Accident Data
(January 1983 - December 1996, All Causes, Commercial and General Aviation)

	National	Texas	Texas / National
Non-Fatal Accidents	31,267	1,932	6.18%
Fatal Accidents	6,208	445	7.17%
Total Accidents	37,475	2,440	6.51%
Total Fatalities	15,480	950	6.14%

Figures 45 and 46 show trends in national rates of general aviation accidents, according to FAA System Indicators data. Figure 46 shows monthly rates of general aviation accidents (in accidents per 100,000 flight hours). A pattern of seasonality is quite apparent. Accident rates increase in the summer months (when presumably there are more flights and flight hours) and decrease in the winter months. The trend line suggests a slight decrease in accident rates over time.

Figure 46 presents a running 12-month national average of general aviation accident rates. As with the first figure, a slight decrease occurs in the accident rate trend line. Interestingly, the data suggest a cyclical pattern in accident rates over a five to six year period.

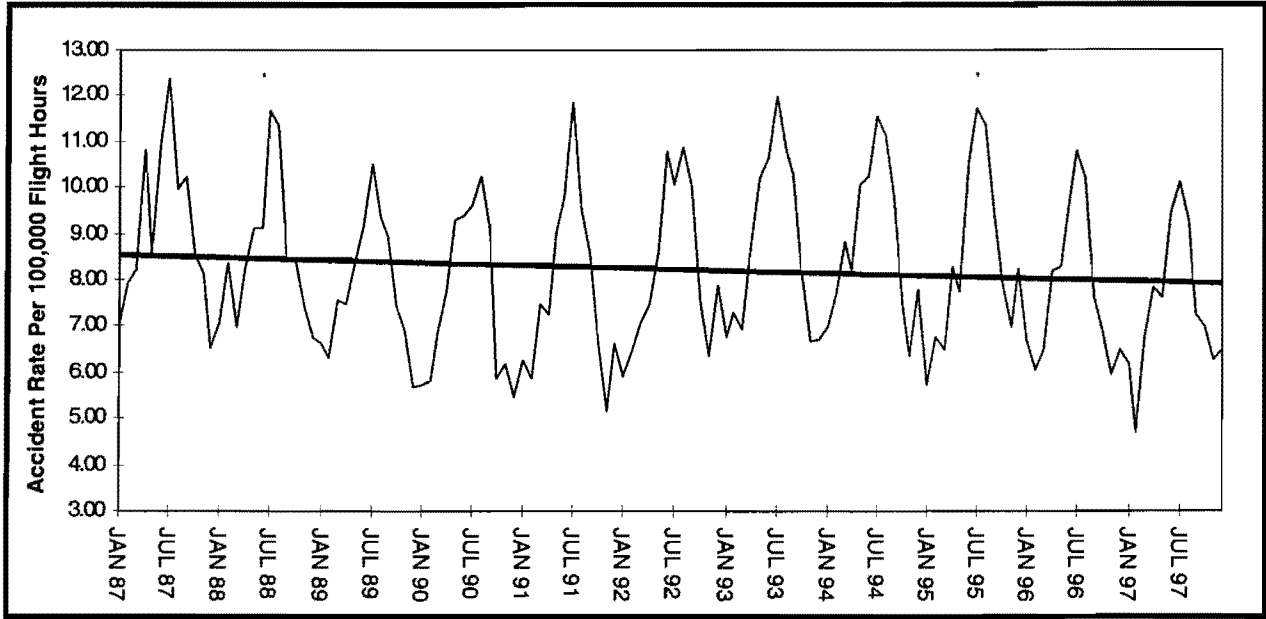


FIGURE 45. Monthly National Rates of General Aviation Accidents
 (Source: FAA Aviation System Indicators)

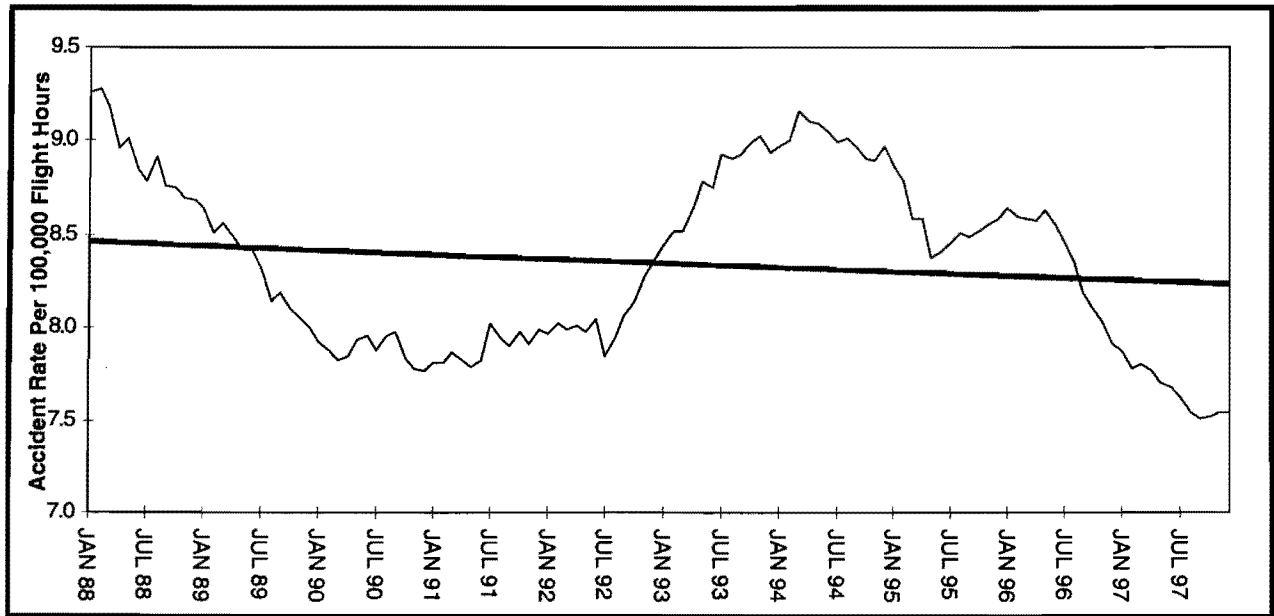
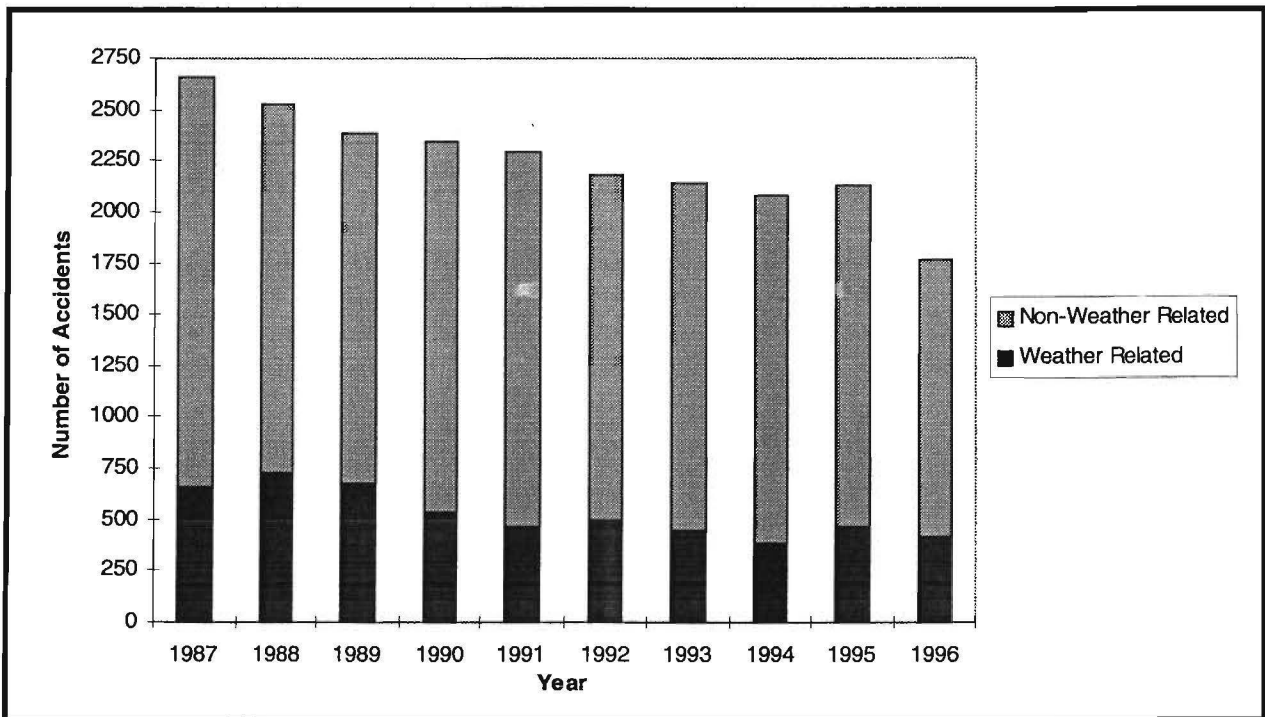


FIGURE 46. 12-Month Average National Rates of General Aviation Accidents
 (Source: FAA Aviation System Indicators)

Information on weather-related accidents, at the national level, is presented in Figures 47-49. The GAO published a report (GAO/RCED-98-130) in June 1998 discussing national aviation safety. The report provided data on the total number of weather-related accidents and fatalities, and on the factors contributing to weather-related general aviation accidents.

Figure 47 shows the national totals of weather and non-weather-related accidents, by year. Figure 48 shows the national totals of fatalities from weather and non-weather-related aviation accidents, by year. Figure 49 shows the national percentages of weather-related general aviation accidents by contributing factor for the period 1987 - 1996.



**FIGURE 47. Total National Weather-Related Accidents
(Commercial and General Aviation, by Year)
(Source: GAO/RCED 98-130)**

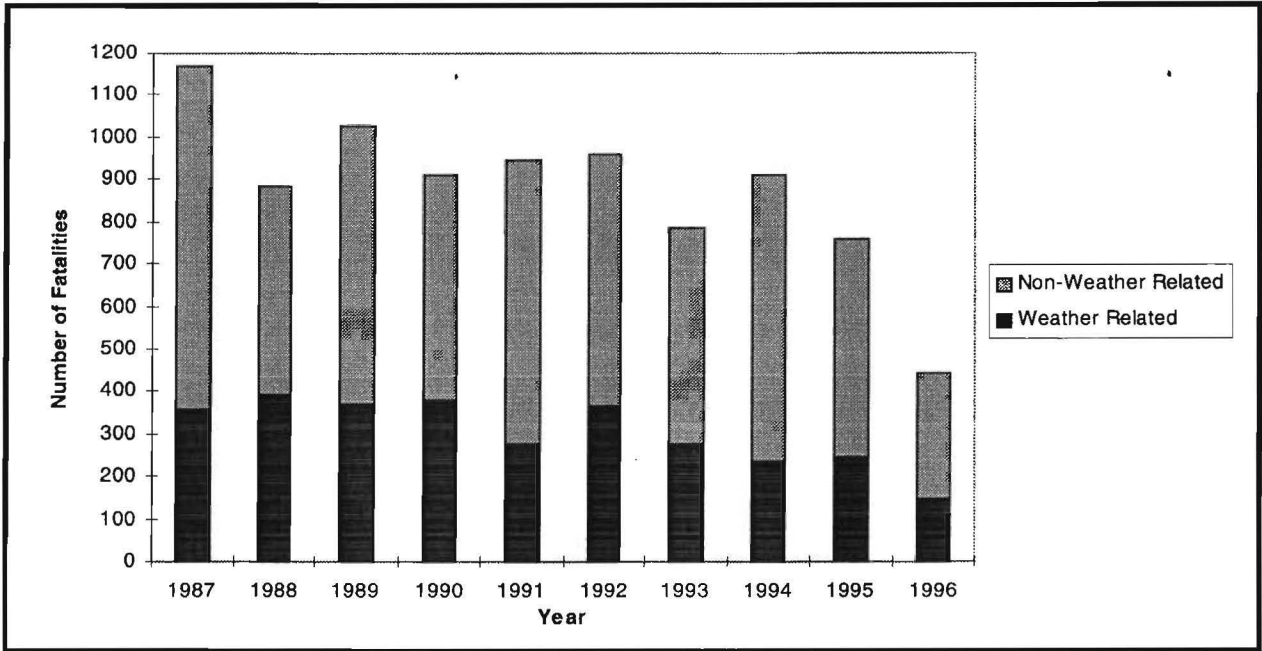


FIGURE 48. Total National Weather-Related Fatalities (Commercial and General Aviation by Year)
 (Source: GAO/RCED-98-130)

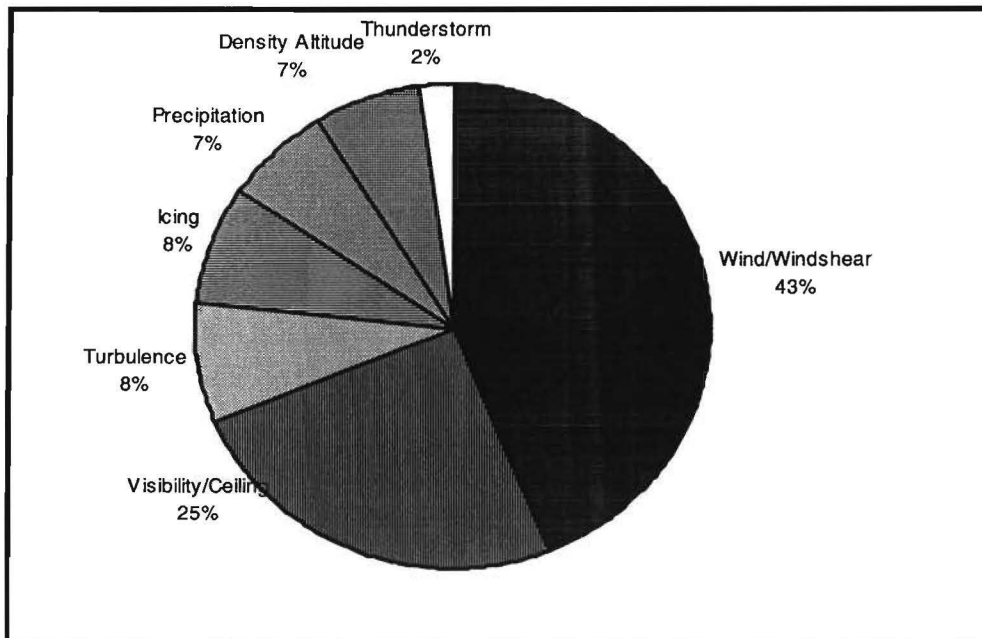


FIGURE 49. National Weather-Related General Aviation Accidents (January 1987 - December 1996)

Texas Accidents

Table 5 shows all Texas general aviation accidents by fatality category (non-fatal and fatal) and by weather category (weather-related and non weather-related). Fatality category is based on the number of fatalities listed in NTSB summary reports. An accident is considered weather-related and placed into weather categories per the probable causes and contributing factors listed in the NTSB accident summary report.

In Texas, during the period from 1983 through 1996, about 21% of all general aviation accidents were weather-related. The proportion of fatal to non-fatal accidents is higher for weather-related accidents than non-weather-related accidents (33%:20%). This difference is statistically significant. Therefore, weather-related accidents appear to be more severe than non weather-related accidents.

Figure 50 shows aggregate Texas general aviation accidents by month for the period 1983 - 1996. The number of weather and non-weather accidents for each month is identified. A pattern of seasonality is present, as the number of accidents is higher in the summer than winter months. This may be a reflection of the pattern in the national accident rates shown in Figure 47.

TABLE 5
Summary of Texas General Aviation Accidents
(January 1983 - December 1996, by Category)

Category	Weather-Related		Non Weather-Related		Total	
	Count	Percentage	Count	Percentage	Count	Percentage
Non-Fatal Accidents	360	15.7%	1,510	65.8%	1,870	81.4%
Fatal Accidents	120	5.2%	306	13.3%	426	18.6%
Total Accidents	480	20.9%	1,816	79.1%	2,296	100.0%

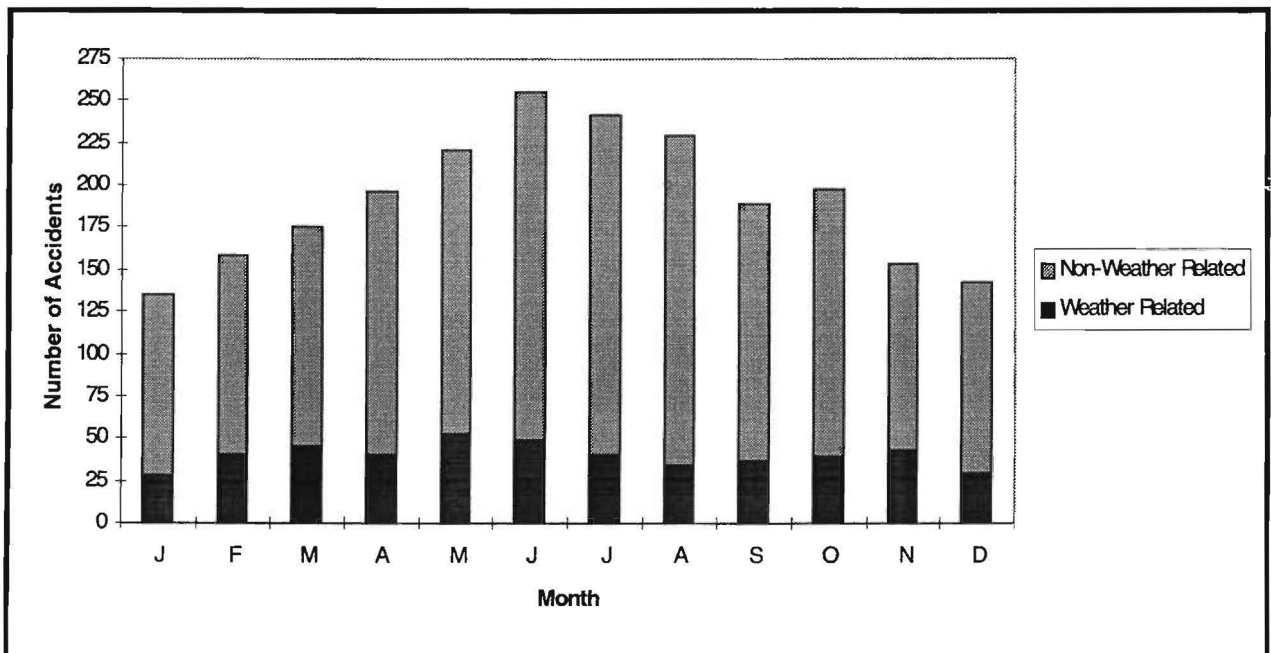


FIGURE 50. Aggregate Texas General Aviation Accidents by Month
(January 1983 - December 1996)

Figure 51 shows the number of Texas general aviation accidents by fatalities per accident. The number of weather and non-weather-related accidents is identified. The percentages of accidents that are weather and non-weather-related are shown in Figure 52 by fatalities per accident.

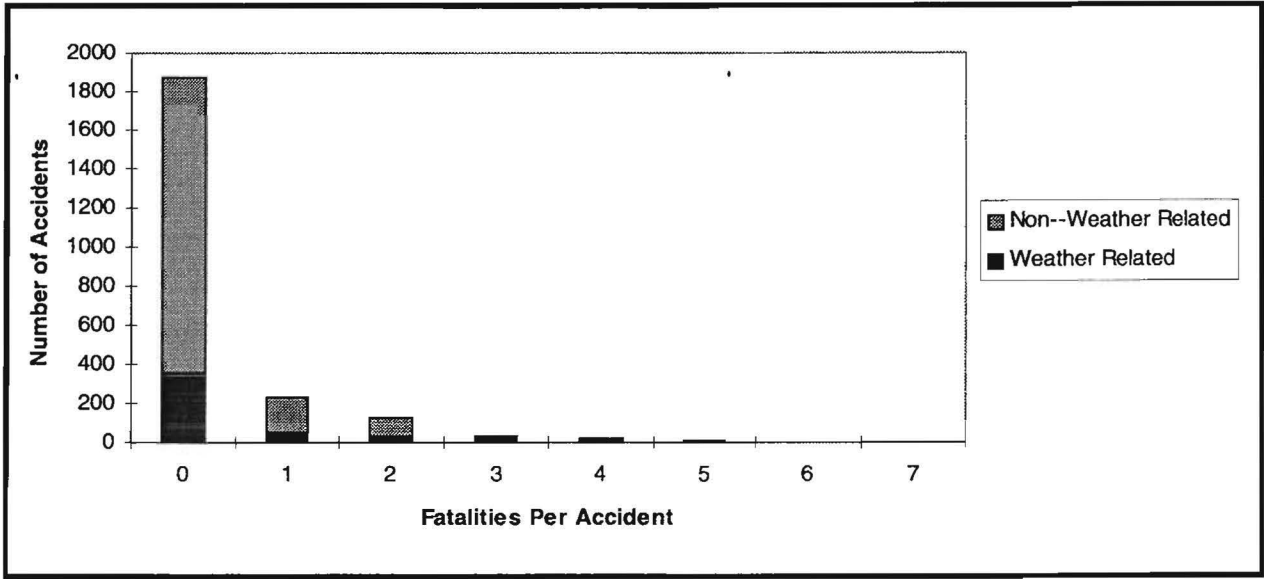


Figure 51. Texas General Aviation Accidents by Fatalities Per Accident (January 1983 - December 1996)

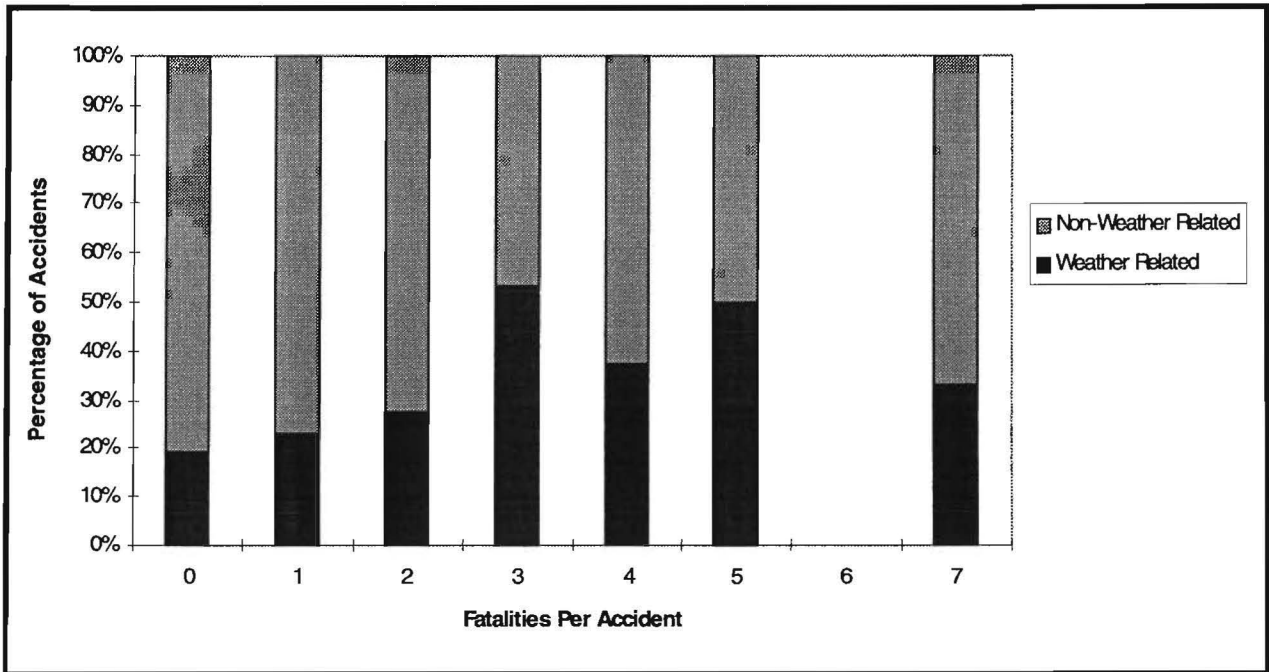


FIGURE 52. Percentage of Texas Weather-Related General Aviation Accidents by Fatalities Per Accident (January 1983 - December 1996)

Texas Weather-Related Accidents by Phase

Table 6 shows Texas weather-related general aviation accidents by phase of flight. Overall, 25% of weather-related accidents involved fatalities. Fatality category differs significantly by phase of flight. The landing phase clearly has the most weather-related accidents (38%).

However, only 5% of all weather-related landing accidents involved fatalities. For example, many accidents during landing involve rolling off the end of a runway. On the other hand, weather-related accidents in the cruise phase of the flight comprised only 19% of all weather-related accidents, but these were fatal almost two-thirds of the time. These patterns are more clearly shown in Figures 53 and 54.

TABLE 6
Summary of Texas Weather-Related General Aviation Accidents by Phase of Flight
(January 1983 - December 1996)

Phase	Non-Fatal		Fatal		Total	
	Count	Percentage	Count	Percentage	Count	Percentage
Approach	36	7.5%	25	5.2%	61	12.7%
Cruise	32	6.7%	58	12.1%	90	18.8%
Landing	174	36.3%	9	1.9%	183	38.1%
Pre-flight	5	1.0%	0	0.0%	5	1.0%
Take off	69	14.4%	16	3.3%	85	17.7%
Other	44	9.1%	12	2.5%	56	11.7%
Total	360	75%	120	25.0%	480	100.0%

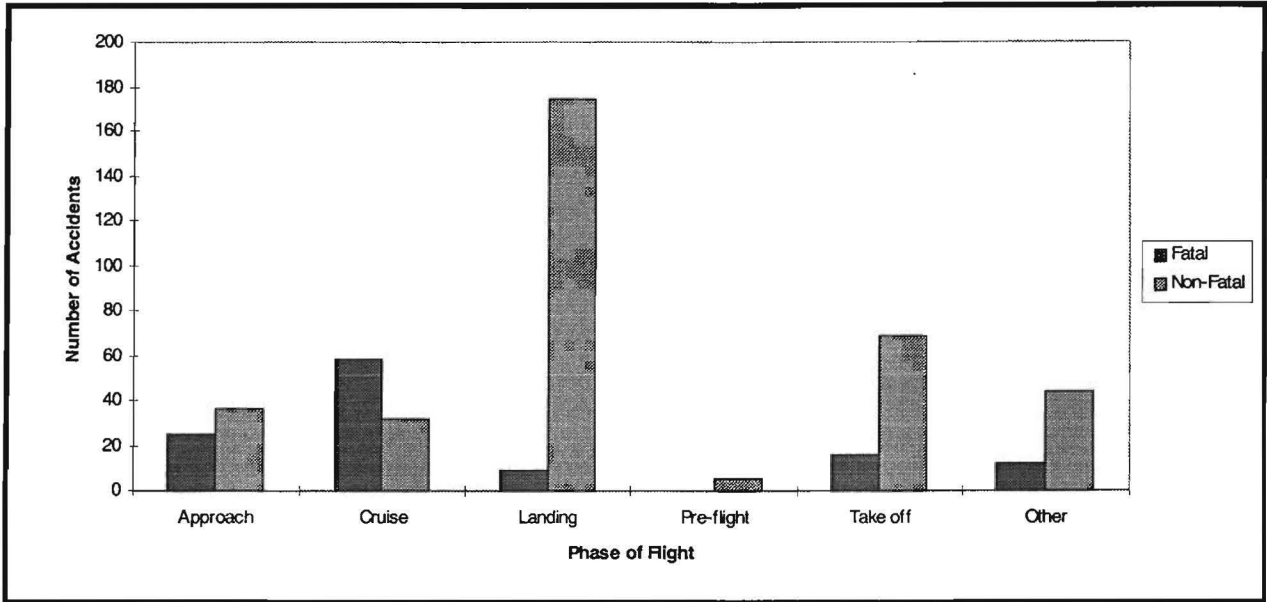


FIGURE 53. Texas Weather-Related General Aviation Accidents, Fatal and Non-Fatal by Phase of Flight (January 1983 - December 1996)

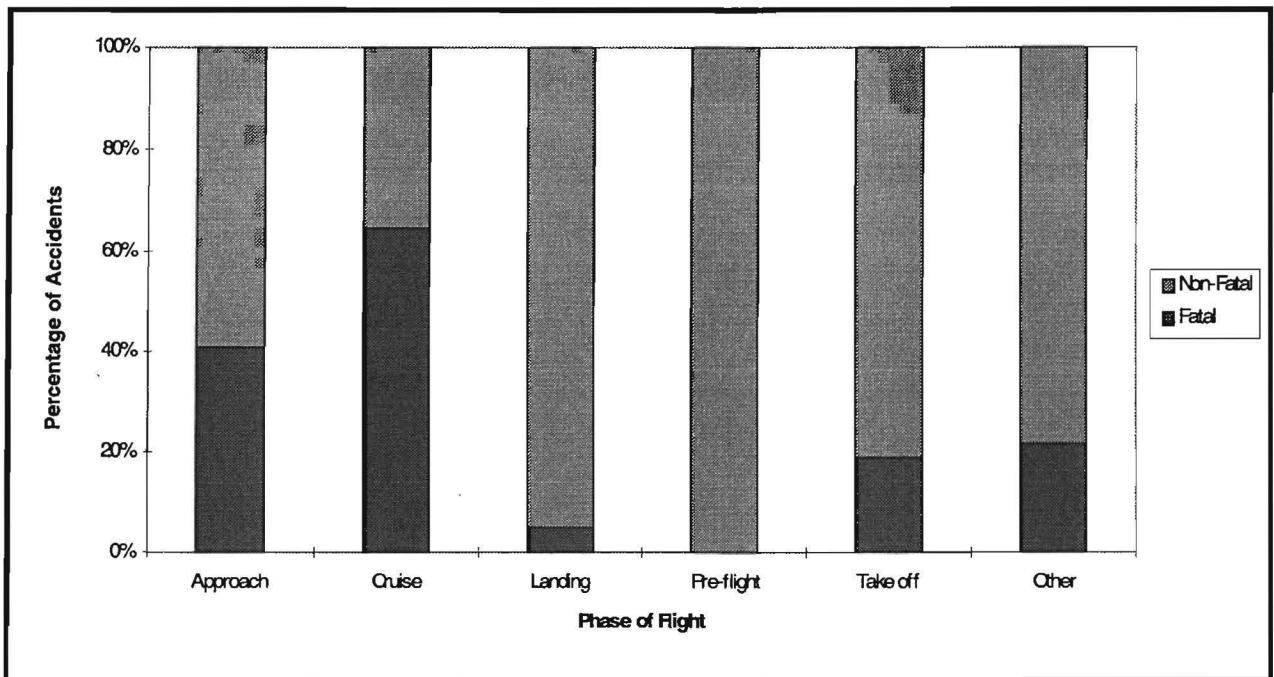


FIGURE 54. Percentage of Fatal Texas Weather-Related General Aviation Accidents by Phase of Flight (January 1983 - December 1996)

Texas Weather-Related Accidents by Cause

Table 7 shows Texas weather-related accidents by probable cause or contributing factor. Cause is assigned by the person preparing the accident report for the NTSB. As with flight phase, fatality category differs significantly by cause. Wind was the most frequent cause of weather-related accidents (53%), but wind-caused accidents were seldom fatal (9%). On the other hand, weather-related accidents caused by the transition from VFR into Instrument Meteorological Conditions (IMC) (although less than 8% of all weather-related accidents) involved a fatality 89% of the time and comprised over 28% of all fatal accidents. These patterns are shown more clearly in Figures 55 and 56.

TABLE 7
Summary of Texas Weather-Related General Aviation Accidents
by Primary Cause or Contributing Factor
(January 1983 - December 1996)

Cause	Non-Fatal		Fatal		Total	
	Count	Percentage	Count	Percentage	Count	Percentage
Aircraft Icing	3	0.6%	1	0.2%	4	0.8%
Low Ceiling	22	4.6%	23	4.8%	45	9.4%
Fog	10	2.1%	16	3.3%	26	5.4%
High Density Altitude	26	5.4%	7	1.5%	33	6.9%
Rain	8	1.7%	0	0.0%	8	1.7%
Snow / Ice	1	0.2%	1	0.2%	2	0.4%
Thunderstorm	6	1.3%	13	2.7%	19	4.0%
VFR into IMC	4	0.8%	34	7.1%	38	7.9%
Wind	252	52.5%	24	5.0%	276	57.5%
Low Visibility	3	0.6%	0	0.0%	3	0.6%
Other	25	5.2%	1	0.2%	26	5.4%
Total	360	75.0%	120	25.0%	480	100.0%

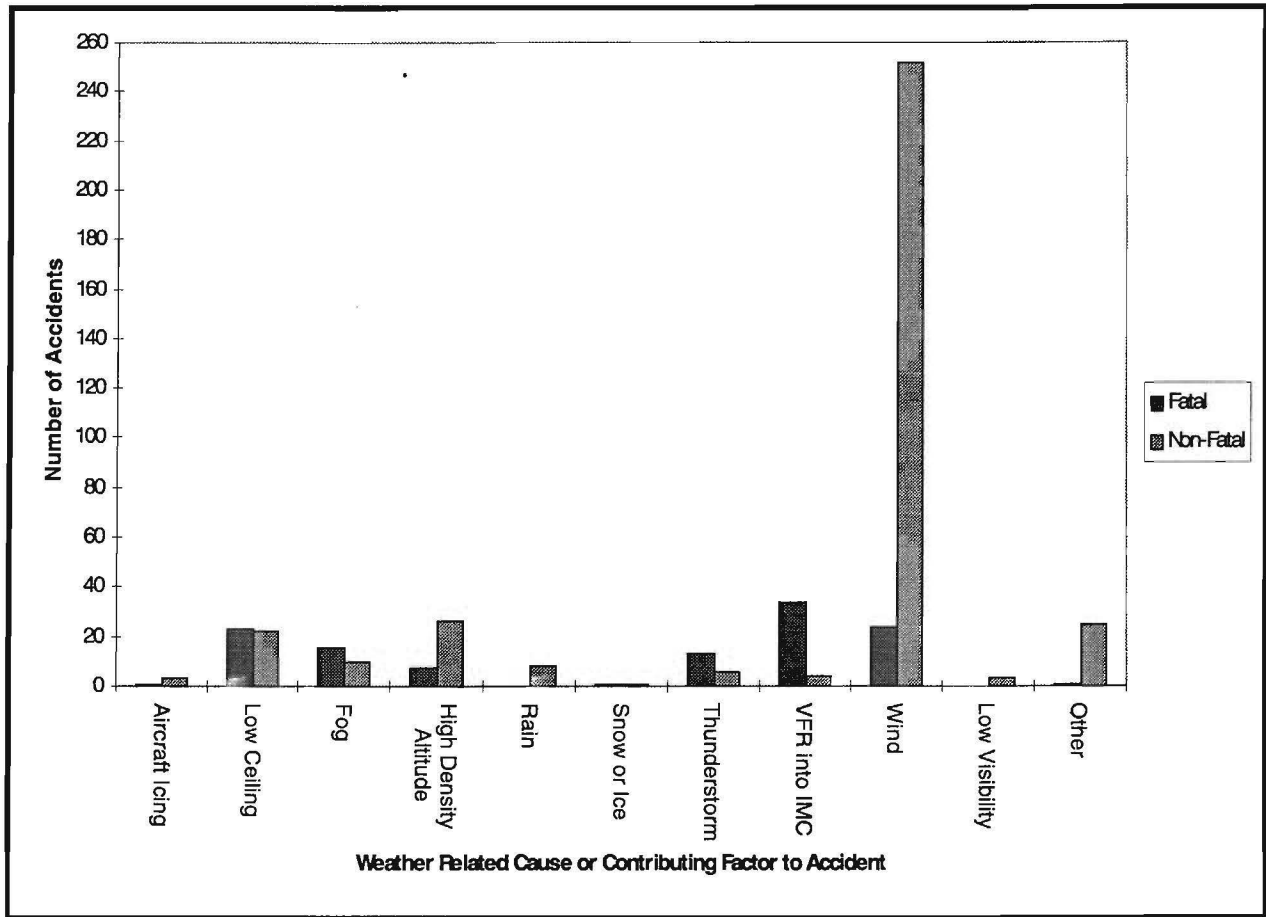


FIGURE 55. Texas Weather-Related General Aviation Accidents, Fatal and Non-Fatal, by Primary Cause or Contributing Factor (January 1983 - December 1996)

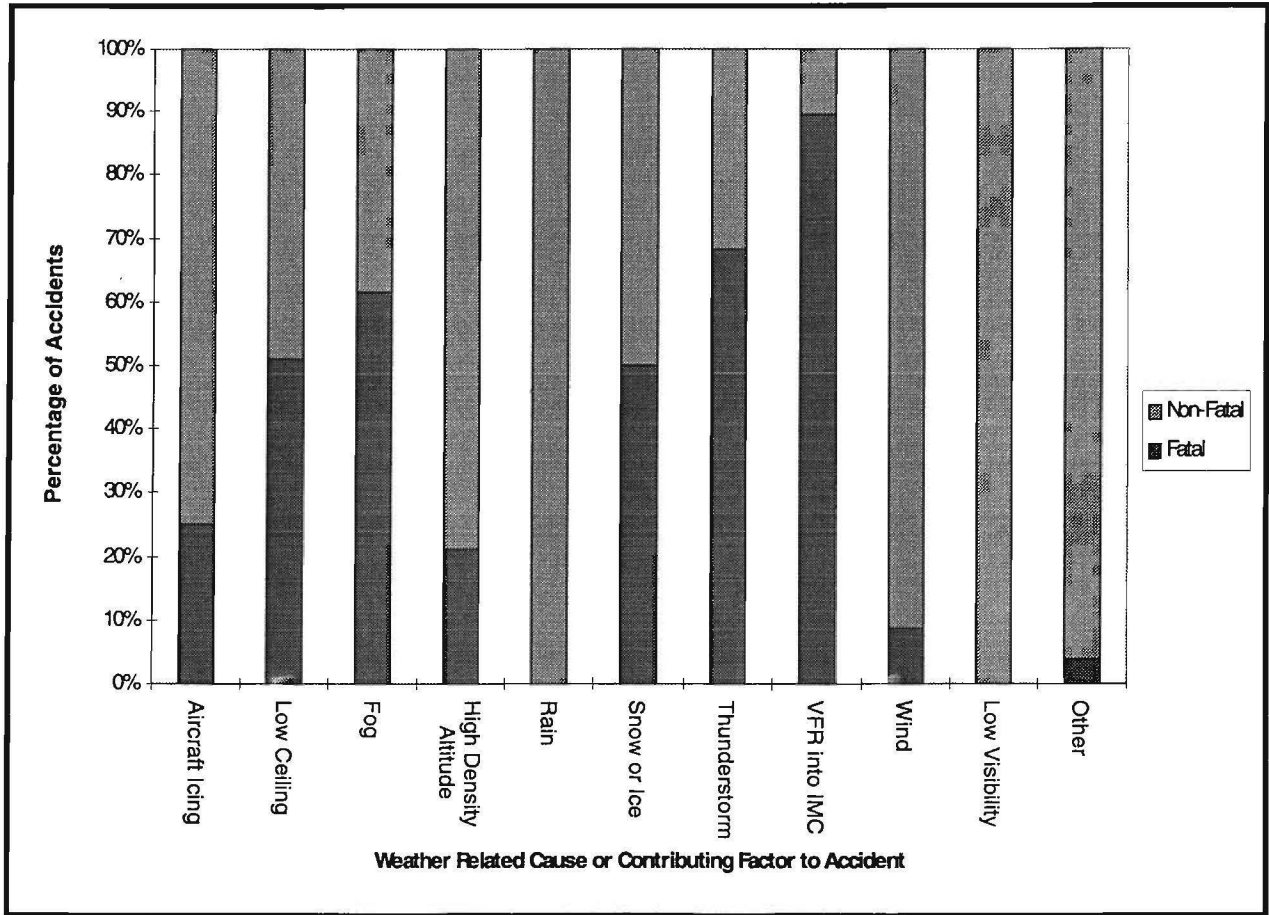


FIGURE 56. Percentage of Fatal Texas Weather-Related General Aviation Accidents by Primary Cause or Contributing Factor (January 1983 - December 1996)

Commercial Versus General Aviation

Although commercial aviation is not the focus of this study, it is informative to compare Texas accident statistics between the two groups. Aircraft involved in Texas accidents were classified in two ways. First, the aircraft were classified as commercial or general aviation. Secondly, each aircraft was classified as either a jet or a non-jet aircraft.

Figure 57 shows the percentage of aviation accidents in Texas that were weather-related. Notice that the percentage of weather-related accidents was about equal for commercial and general aircraft. Jets and non-jets also had about the same percentage of weather-related accidents.

Figure 58 shows the percentage of fatal aviation accidents in Texas (weather and non weather-related). Commercial and general aviation has about the same percentage of fatal

accidents. As one might expect, however, jets had a much lower percentage of fatal accidents than non-jets.

Finally, the percentage of fatal weather-related aviation accidents in Texas are shown in Figure 59. As with Figure 58, commercial and general aviation had about the same percentage of fatal accidents, and jets had a much lower percentage of fatal accidents than non-jets.

Since commercial and general aviation had roughly the same percentage of weather-related accidents, fatal accidents, and weather-related fatal accidents, it is likely that improved weather data collection and dissemination would not only benefit commercial aviation but would also benefit general aviation.

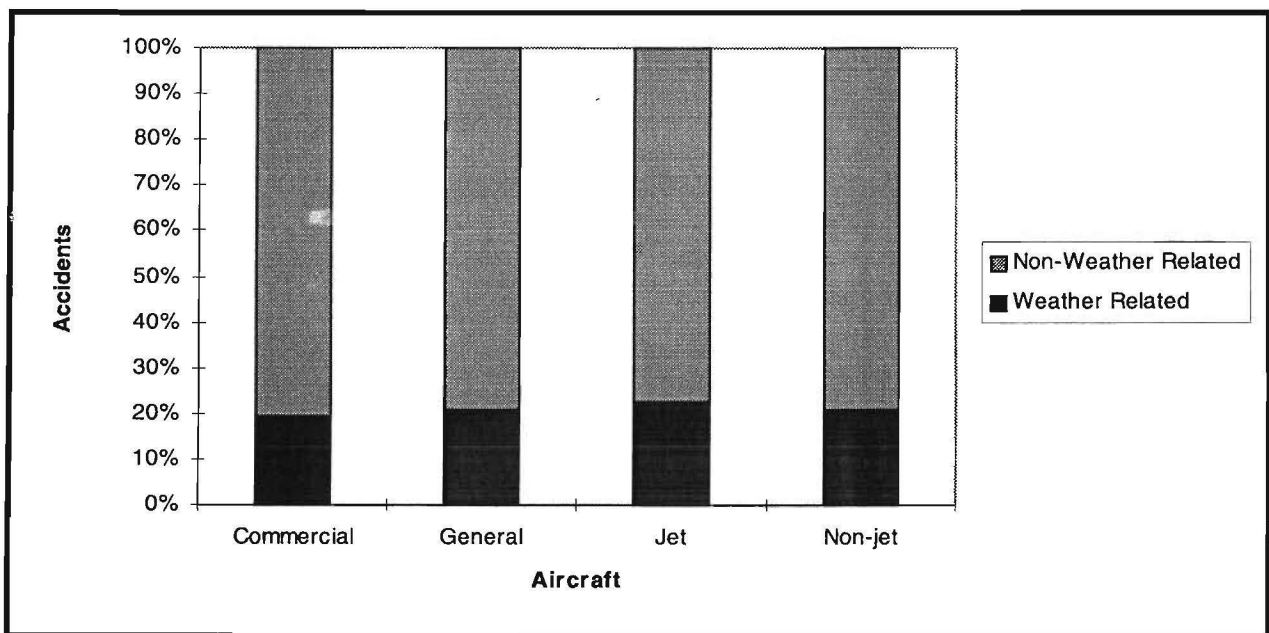


FIGURE 57. Percentage of Weather-Related Texas Aviation Accidents by Aircraft Type (January 1983 - December 1996)

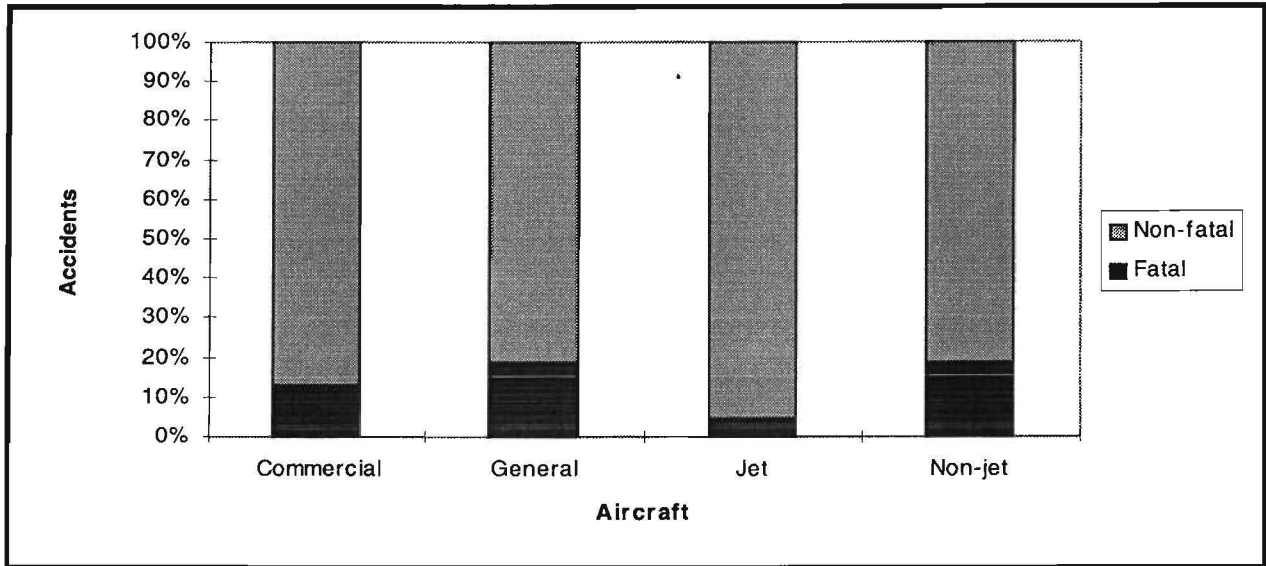


FIGURE 58. Percentage of Fatal Texas Aviation Accidents by Aircraft Type (January 1983 - December 1996)

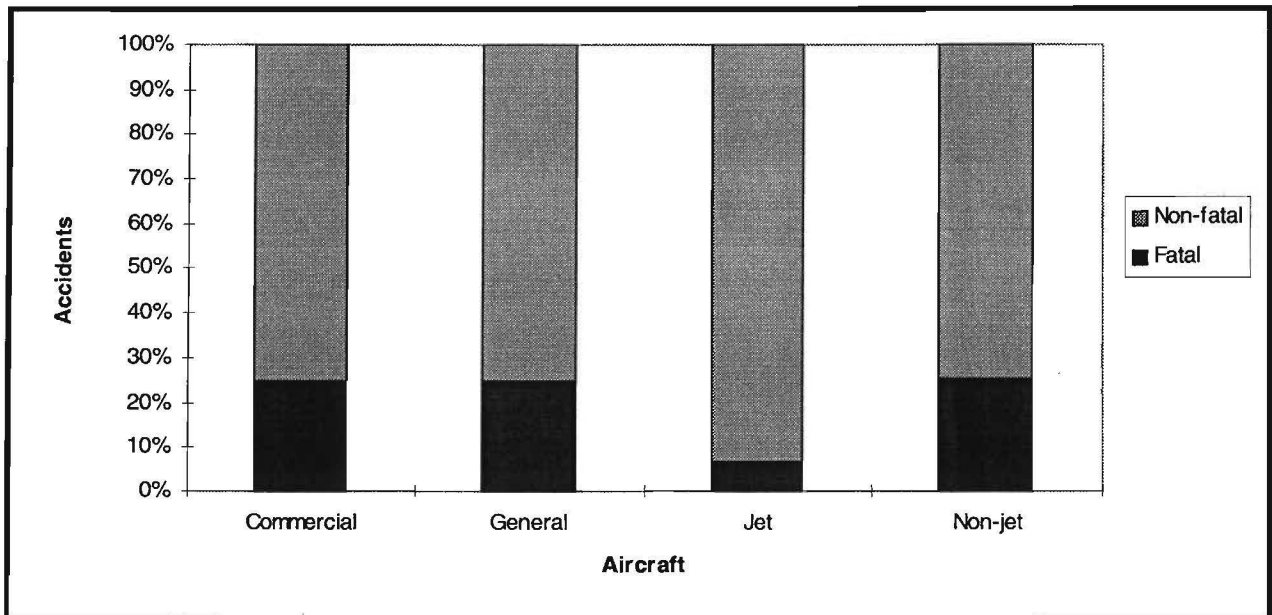


FIGURE 59. Percentage of Fatal Texas Weather-Related Aviation Accidents by Aircraft Type (January 1983 - December 1996)

Statistical Methodology

The fatality category (fatal versus non-fatal) is a critical variable in this analysis, as well as in the entire study. The significance of the fatality category was examined two ways. The Chi-Square statistic addresses the differences between the observed and expected frequencies, that is, general association. Chi-Square is a nonspecific test of association in that there is no assumed direction of association. Chi-Square is, however, somewhat sensitive to sample size in that results are unreliable if many cells have less than five observations or if expected frequencies in any cells are less than one (i.e., fractional). Clearly, the former may be the case, though the latter is less likely.

The Cochran-Mantel-Haenszel (CMH) statistic tests the null hypothesis that there is no association between the observations in either the rows or columns. When the null hypothesis is true, the CMH statistic is approximately distributed as Chi-Square. CMH statistics have limited power to detect associations that are in the opposite direction of other associations. That is, CMH is effective for detecting patterns of association across strata (i.e., rows or columns) where there is reason to expect the majority of the differences to have the same sign. Consequently, a nonsignificant CMH statistic may mean that there is no association or that there is no dominant pattern of association (which for our purposes is the same thing). The CMH statistic, however, is less stringent in cell size requirements compared to the Chi-Square. The CMH requires only a reasonably large overall sample. Hence the use of CMH in addition to Chi-Square.

CHAPTER 7. CONCLUSIONS

A wide range of weather information sources have been identified and described, including their respective communication paths and dissemination methods. This inventory of weather data collection and dissemination systems clearly demonstrates that the collection of weather data is distinct and separate from its dissemination. There are relatively few primary weather data collection sources (e.g., NWS), while there are a multitude of intermediary processing and interpretation agencies and firms (e.g., commercial outlets). In addition, several collection and dissemination sources are in transition.

Consequently, the ability or willingness of existing dissemination and communication systems to share intermediate level weather data is somewhat limited now (largely due to organizational rather than technological limitations), and some cross-modal sharing may never be total (e.g., marine/aviation). However, changes currently in progress appear to be addressing many of these limitations. Finally, the sharing or dissemination of weather data from multiple sources can be enhanced from the user end as well. This is accomplished by making potential users aware of and familiar with sources outside their primary modal interest (i.e., user training and education).

The numerous sensors and overlapping dissemination systems and networks within Texas demonstrate the potential for synergistic uses of the gathered data. The transportation, construction, agriculture, and energy industries, as well as the media, all have the need for improved weather data. However, the effort to obtain improved data is often fragmented and unorganized.

Coordinating weather collection and dissemination efforts between state agencies, private industry, the NWS, and the FAA will lead to improvements in the quality and timeliness of the generated data. There is also a need to standardize sensor design and construction, and to use sensors that are capable of communicating with control and monitoring equipment on a standard protocol.

Low-cost sensors are on the near horizon and will allow TxDOT to extend its weather data collection activities to lower volume roads in remote locations. There is also the need to explore the use of mobile sensors. One potential application of the practice is the installation of sensors on highway patrol vehicles. These sensors could effectively measure and report visibility, pavement conditions, pavement temperatures, and road friction.

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12. Boo Walker, Texas Forest Service, Lufkin, TX, 6 May 1998.
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APPENDIX A
LITERATURE REVIEW

INTRODUCTION

The first step in studying the sources, manipulation, and dissemination of weather data in Texas was to methodically search the existing literature for documents relating to the subject. The review of these documents provided a productive background study of the material describing the state-of-the-art.

One cause for concern during this early phase of the study was the rapid change occurring in the art and, more important, science of weather data collection and use. Years ago the FAA and NOAA divided the Advisory Circular into two parts: *Aviation Weather, AC 00-6A*, and *Aviation Weather Services, AC 00-45*. This allowed for more efficient updating of the Circular since the AC 00-45 Circular, outlining weather services provided, is updated more frequently than the 00-6A Circular, which outlines weather principles and physics. Even though the AC 00-45 Circular was updated in 1996, in many ways it is now (1988) obsolete.

Researchers used catalogs and databases provided by The Texas A&M University System Libraries for the literature review. The results of this review are on the subsequent pages of this document. Researchers searched the NOTIS and WorldCat Catalogs and the Science and Technology and Interdisciplinary Databases. Researchers found a multitude of references on the subject and pared them to a more manageable size by eliminating dated (before 1982) and unrelated titles.

BOOKS

The following abstracts describe books relevant to understanding weather phenomena and how weather data is transmitted and used.

1. Buck, Robert N. *Weather Flying*. New York: Macmillan Publishing Co. Inc., 1978.

This is a book discussing flying conditions from a pilot's perspective. Buck is an experienced airline pilot with additional expertise as a military, glider, general aviation, and instructor pilot. He has a consummate interest in meteorology and how the prudent pilot must consider less than ideal flying conditions when departure is imminent. The material in this book provides guidance to pilots making these decisions.

2. National Research Council. *Toward a New National Weather Service—A First Report*. National Weather Service Modernization Committee. Washington, D.C.: National Academy Press, 1991, and
3. National Research Council. *Toward a New National Weather Service—Second Report*. National Weather Service Modernization Committee. Washington, D.C.: National Academy Press, 1992.

These reports, prepared by the select National Weather Service (NWS) Modernization Committee of the National Research Council, suggest methods to implement the most cost effective levels of technical systems and services by assessing NWS technological and scientific capabilities for availability, applicability, and timing. Additionally, the authors suggest that reviewing test, demonstration, and certification plans, and independently reviewing data collection and interpretation processes will assist in the successful demonstration and acceptance of the modernized and restructured NWS operations.

4. Collins, Richard L. *Flying the Weather Map*. New York: Delacorte Press/Eleanor Friede, 1979.

The author briefly discusses the weather phenomena of interest to pilots, how these phenomena are depicted on the weather chart, and how pilots use this data for making go/no-go (and which way-to-go) decisions prior to flight commencement. The second half of the book is a log covering about one-year of flights in all seasons, described from the perspective of the weather map discussion.

5. Morrison, Tom. *Weather for the New Pilot*. Ames, IA: Iowa State University Press, 1991.

Written for the new pilot, this book discusses the meteorology of weather and how inexperienced pilots can use this information. The presentations are theoretically, sound yet simple enough for practical use by pilots who have little experience with the behavior of weather and its great influence on flying.

6. Lindsay, Charles, V. *A Handbook of Soaring Meteorology*. Virginia Beach, VA, 1988.

A very specialized discussion of weather phenomena and its importance to soaring. The book includes a section on basic meteorology and a larger section on soaring meteorology. This latter section addresses thermal soaring, wave soaring, and ridge soaring. This section details the importance of forecasting conditions conducive to soaring.

7. Nelson, John L. *Practical Guide to Aviation Weather*, 2nd ed. TAB Books, Inc., 1984.

This weather discourse is oriented toward the needs and safety of the VFR-only pilot. The book covers meteorology, services available to the pilot, and the decision-making process the pilot must follow during the preflight planning phase. The book is becoming obsolete.

8. Griffin, Jeff W. *Pilot's Guide to Weather Forecasting*. TAB Books, Inc., 1984.

This publication discusses the elemental aspects of meteorology for the beginning pilot. It concentrates on how the pilot uses his or her knowledge of clouds, fronts, and pressures, and their depiction on a weather chart, to forecast weather along a flight route. This book is rapidly becoming dated (late 1997).

9. Buck, Robert N. *The Pilot's Burden (Flight Safety and the Roots of Pilot Error)*. Ames, IA: Iowa State Press, 1994.

This book describes the history of a pilot during Buck's active years (1930-1994). It details technological advances in aviation equipment, but more important, the impact these advances had on pilots. A significant part of the history discusses weather and its role in incidents and accidents, and its impact on equipment and pilots. Many advances outlined in this book did not improve operations or safety.

10. Oster, Clinton V., Jr., John S. Strong, and C. Kurt Zorn. *Why Airplanes Crash: Aviation Safety in a Changing World*. New York: Oxford University Press, 1992.

This book provides a statistical, economic and political look at when and why airplanes crash, particularly considering such factors as the airline deregulation that began in 1978. In addition to the competitive pressures resulting from deregulation, other factors considered in detail include terrorism and the aging airplane fleet. While weather-related accidents are not an important element in the outline of this book, they are such an important factor that the subject literally demands some attention.

11. Ellis, Glenn. *Air Crash Investigation of General Aviation Aircraft*. With contributions by C.O. Miller and J.M. Ramsden. Greybull, WY: Capstan Publications, Inc., 1984.

The book is a detailed checklist for aviation accident reconstructors. Subjects discussed include: procedures to follow when first arriving on the scene of an accident, who will be involved in the investigation, establishing facts, interviewing witnesses, and potential liabilities. While the frequency and seriousness of weather-related accidents is mentioned, it is not a point of emphasis. However, the need to find and record, in a detailed format, weather conditions at the time of the accident is described.

12. Barr, James C. *Airborne Weather Radar: A User's Guide*. Ames, IA: Iowa State University Press, 1993.

This paperback discusses procedures to effectively use airborne weather radar. It provides a generic discussion of the equipment and guidance on interpreting and using the echoes displayed on the plan position indicator (PPI). The author discusses the significance color display, but significance of the descriptions are somewhat stifled since all of the figures are in black, shades of gray, and white.

13. Knauth, Percy. *Safety in the Skies*. Blue Ridge Summit, PA: TAB Books, Inc., 1982.

This paperback traces the history of manned flight from the early open-cockpit days to the high-speed jets of today. The book emphasizes the high cost—in terms of accidents and dollars—of bringing the industry to the incredibly safe status it enjoys today. The author also

discusses the potential for increased safety and comfort that new technology will bring. One short chapter is devoted to weather and its importance to the aviator, but the material and conclusions have lost much of their significance since 1982.

14. Wells, Alexander T. *Flight Safety: A Primer for General Aviation Pilots*. Blue Ridge Summit, PA: TAB Books, Inc., 1992.

This is a text for the student pilot, primarily the Private Pilot Certificate candidate. It is a clear, concise well-written book. The author emphasizes training to minimize incidents resulting from weather hazards (especially cold weather), night flying, and physiological factors. What weather information the pilot needs and procedures for obtaining the information is emphasized.

15. Anderson, John D., Jr. *Introduction to Flight*, 3rd ed. New York, NY: McGraw-Hill Book Company, Inc., 1989.

This is a beginning text for aerospace engineers that covers the conventional aspects of aerospace engineering from a historical and technological standpoint. In particular, the author defines the standard atmosphere in detail.

16. Byers, Horace Robert, Sc. D. *General Meteorology*, 3rd ed. New York, NY: McGraw-Hill Book Company, Inc., 1959.

A text for the serious meteorology student. The author develops mathematical depictions of weather phenomena from the first principles of statics, heat transfer, and thermodynamics. The author also discusses weather sensing instruments in common use at the time the book was published. While the author mentions the consequences of some weather conditions to pilots and sailors, this is a book primarily for meteorologists.

17. Djuric, Dusan. *Weather Analysis*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1994.

This book is a text for a first course in weather analysis. The author presupposes that the student is familiar with weather systems, the equations of motion, hydrostatics, continuity, the first law of thermodynamics, and geostrophic approximation. Further, the author expects that readers are familiar with methods of observation, transmission of data, and basic construction of synoptic weather charts. The purpose of this well-written book is to present all three facets of weather analysis: techniques, the physics of weather processes, and the structure of circulation patterns.

18. Kessler, Edwin, ed., *The Thunderstorm in Human Affairs*, 2nd ed. (Vol. 1 of *Thunderstorms: A Social, Scientific, and Technological Documentary*). Norman, OK: University of Oklahoma Press, 1983.

This book addresses several social aspects of violent thunderstorms including dangers (wind, hail, flood) and difficulty in forecasting. Each chapter is prepared by an expert in the respective field covered. The chapter on Thunderstorms and Aviation, written by J. T. Lee, a meteorologist with the National Severe Storms Laboratory, Norman, OK, and W. B. Beckwith, a former meteorologist with United Airlines (Ret) and meteorological consultant, discusses some of the dire consequences suffered by airplanes as a result of the forces of violent thunderstorm. The book includes statistics of accidents from 1964 through 1981 resulting from encounters with thunderstorms.

19. Collins, Richard L. *Thunderstorms and Airplanes*. New York, NY: Delacorte Press, 1982.

This rudimentary book is aimed primarily at the general aviation pilot. The author does not encourage pilots to go out and fly through thunderstorms, but provides an understanding of what thunderstorms are, what they do, how they affect airplanes, and what pilots can do to avoid them. The author discourages attempts to legislate safety in stormy weather, and recommends education and the use of good judgement as pilots view and avoid thunderstorms.

20. Ahrens, C. Donald. *Meteorology Today An Introduction to Weather, Climate, and the Environment*, 5th ed. Minneapolis/St. Paul, MN: West Publishing Company, 1994.

This excellent text is designed for college-level students enrolled in an introductory atmospheric environment course. The author discusses, through words and color photographs, everyday experiences with weather, and stresses the understanding and application of meteorological principles. The author emphasizes watching the weather so that it becomes “alive,” allowing the reader to immediately apply textbook material to real world situations. This is a substantive book, addressing current atmospheric issues and methods of weather forecasting. It is an ideal text for the beginning meteorologist, but is not aviation oriented.

21. Stull, Roland B. *Meteorology Today for Scientists and Engineers*. (A technical companion book to *Meteorology Today, An Introduction to Weather, Climate, and the Environment*) Minneapolis/St. Paul, MN: West Publishing Company, 1995.

This book corresponds, virtually chapter by chapter, with the book above, except that it is predicated on an overt presentation of the physics and mathematics at work in the atmosphere. While the author omits many derivations and calculus, the text includes many equations and formulae. The author works out many numerical examples and presents them often using spreadsheet software currently available for digital computers.

22. Trollop, Stanley R., and Richard S. Jensen. *Human Factors for General Aviation*. Englewood, CO: Jeppesen Sanderson, Inc., 1991.

This informative text discusses human behavior in the general aviation environment and how that behavior is frequently the direct cause of accidents. An important part to a weather data study is how the pilot collects and uses weather information to make judgements, both cognitive and perceptual. This text discusses the process of collecting information and the process of using the information to make sound judgements, independent of the external pressures and parameters.

23. Lester, Peter F. *Aviation Weather*. Englewood, CO: Jeppesen Sanderson, Inc., 1997.

This is a well-written book concerning weather and the weather needs of all pilots. While the author presents a minimum of mathematics, the concepts covered are not trivial. The interdependence of aviation and meteorology is emphasized from the standpoint of the pilot making go/no-go decisions. The extensive use of color photographs and diagrams keeps the subject matter interesting and the reader involved. The weather terms glossary and the current list of references were helpful to the reviewers.

24. Federal Aviation Administration (FAA). *Aviation Weather, AC 00-6A*. U. S. Department of Transportation, FAA, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), NWS. Washington, D.C., 1995.

This and the next reference, both Advisory Circulars, are companion manuals published jointly by the FAA and the NWS. This text discusses weather principles and phenomena and intentionally avoids all mention of specific weather services. As a consequence, it is expected that the document will remain valid and adequate for many years. The FAA will frequently update the supplementary text, *Aviation Weather Services, AC 00-45D*, as new techniques and capabilities are available.

25. FAA. *Aviation Weather Services, AC 00-45D*. U. S. Department of Transportation, FAA, and U.S. Department of Commerce, NOAA, NWS. Washington, D.C., 1995.

Due to the rapid expansion of air transportation and increased aviation demands, it is necessary for pilots to move toward self weather briefings. Pilots must become increasingly self-reliant in obtaining weather information. This Advisory Circular explains weather service in general and provides guidance for interpreting and using coded weather reports, forecasts, and observed and prognostic weather charts. Many charts and tables apply directly to flight planning and in-flight decisions.

26. AOPA Air Safety Foundation. *General Aviation Weather Accidents, An Analysis & Preventive Strategies*. Frederick, MD, 1996.

This study, conducted by the Air Safety Foundation, but funded by the Flying Physicians Association, is directed specifically toward weather-related aviation accidents. This document is extremely pertinent for anyone interested in weather data for pilots. This document is a plan of action for the research team on this project. Recommendations suggest that flight instructors tailor their instruction toward eliminating weather-related accidents.

PRESENTATIONS

Three recent international aviation weather systems conferences have particular significance to this study. The American Meteorological Society sponsored all three conferences. A number of presentations at each conference pertained to aviation weather issues in Texas. Some of the more pertinent presentations included:

1. The American Meteorological Society. *Fifth International Conference on Aviation Weather Systems*. Preprints, Vienna, VA, 1993.
 - a. Sankey, David A., FAA, Washington, D.C. *An Overview of FAA-Sponsored Aviation Weather Research and Development*. Presented at the American Meteorological Society Fifth International Conference on Aviation Weather Systems, Vienna, VA, 1993.

The author discusses current methods of gathering, processing, and distributing weather information used by the FAA and the NWS, and enumerates opportunities for improving these methods. Primarily the author discusses research directed toward improving the resolution, both in time and space, of the products. The author describes the FAA and NOAA joint development effort for the Mesoscale Analysis and Prediction System (MAPS). Other future acronyms mentioned in the paper included:

SAV State of the Atmosphere Variables (temperature, pressure, humidity, etc.)
AIV Aviation Impact Variables (icing, turbulence, ceiling and visibility, etc.)
NMC National Meteorological Center
ACARS Aircraft Communications, Addressing and Reporting System
AGFS Aviation Gridded Forecast System (turns SAV's to AIV's)
AWPG Aviation Weather Product Generator
ITWS Integrated Terminal Weather System
NEXRAD Next Generation Weather Radar (terminal Doppler radar)

- b. Heuwinkel, Richard, FAA, and Kelly Connolly and Graham Glover, The MITRE Corporation, Center for Advanced Aviation System Development (CAASD), McLean, VA. *National Aviation Weather Program Plan*. Presented at the American

Meteorological Society Fifth International Conference on Aviation Weather Systems, Vienna, VA, 1993.

This presentation detailed the published National Aviation Weather Program Plan (NAWPP), listing the current unmet aviation weather needs. They include:

- improve and update user education for pilots and other users;
 - improve the capability to provide automated, direct access to consistent tailored weather information to pilots in-flight;
 - improve the capability to provide user access to consistent, preflight weather information;
 - develop the capability to provide weather products tailored for the specific mission and skills of each user (pilot, controller, flight service specialists);
 - improve the quality of observations, nowcasts and forecasts for ceiling and visibility;
 - improve the quality of observations and forecasts for thunderstorms, turbulence and icing to support terminal and en-route operations;
 - improve the quality and coverage of microbursts, wind shear, gust fronts and severe low-level winds observations and forecasts for terminal areas; and
 - develop an inter-agency plan to ensure continuity of research and related programs necessary to improve forecasting technology.
- c. Albersheim, Steven R., and Richard J. Heuwinkel, FAA, and Ann Marie Scalea, The MITRE Corporation. *Transitioning to the Aviation Routine Weather Report (METAR) and the International Aerodrome Forecast (TAF) Within the Federal Aviation Administration*. Presented at the American Meteorological Society Fifth International Conference on Aviation Weather Systems, Vienna, VA, 1993.
- d. Alm, Nathan P., Leon F. Osborne, and Michael R. Poeliot, University of North Dakota. *Aviation Weather Education and the University of North Dakota Aviation Weather Survey*. Presented at the American Meteorological Society Fifth International Conference on Aviation Weather Systems, Vienna, VA, 1993.
2. American Meteorological Society. *Sixth Conference on Aviation Weather Systems*, Preprints, Dallas, TX, 1995.
- a. McCullough, Carl P., Weather System Manager, FAA, and Laurence M. Gordon and Sadeh Kavoussi, The MITRE Corporation CAASD. *The FAA's Aviation Weather System Plan*. Presented at the American Meteorological Society Sixth Conference on Aviation Weather Systems, Dallas, TX, 1995.

This presentation is an update on the accomplishments of the FAA's 1994 Weather System Plan. It is expected that by the late 1990's, the Advanced Weather Interacting Processing System (AWIPS) using multiple data sources will become operational. The AGFS will provide the

capability of using the multiple sources to produce a variety of needed weather products. Included among the sensor inputs to the AGFS is the new Aircraft Communications, ACARS, an automatic system for sensing weather conditions from departing, or arriving, airplanes. At about the same time, the FAA will introduce ITWS at approximately 40 to 50 U.S. airports where the NEXRAD Doppler weather radar is being installed. This will assure detailed definitions of weather hazards in the terminal areas.

- b. Ellrod, Gary P., Office of Research and Applications (NOAA/NESDIS), Washington, D.C., and James P. Nelson, Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin, Madison, WI. *Benefits of the Advanced GOES Satellites to Aviation Users*. Presented at the American Meteorological Society Sixth Conference on Aviation Weather Systems, Dallas, TX, 1995.

This presentation describes the capabilities of the I through M series for the Geostationary Operational Environmental Satellite (GOES). Because of lower instrument noise levels and additional window infrared channels, the resolution is greatly improved over that of the GOES-VAS. These enhancements should provide improvements in the routine detection of aviation hazards such as convective storms, fog, stratus, and mountain waves. Additionally, these enhancements should provide better derived products such as cloud motion wind vectors, Lifted Index, Precipitable Water, and cloud heights.

3. American Meteorological Society. *Seventh Conference on Aviation, Range, and Aerospace Meteorology*, Preprints, Long Beach, CA, 1997.

- a. Starr, Kevin M., TRW Government Information Systems Division, Fairfax, VA, and Craig Goff, FAA, Office of System Integration Analysis, Washington, D.C. *The FAA's Weather System Architecture and Integration*. Presented at the American Meteorological Society. Seventh Conference on Aviation, Range, and Aerospace Meteorology. Long Beach, CA, 1997.

This presentation describes the weather systems envisaged for the FAA during the next several years. Of particular importance is the description of the Weather and Radar Processor (WARP) for en-route weather and the ITWS for terminal area weather.

- b. Sankey, David A., and Kenneth M. Leonard, FAA, Warren Fellner and David J. Pace, AMETCH, Inc., Washington, D.C., and Kenneth L. Van Sickle, National Science Foundation, Arlington, VA. *Strategy and Direction of the Federal Aviation Administration's Aviation Weather Research Program*. Presented at the American Meteorological Society. Seventh Conference on Aviation, Range, and Aerospace Meteorology. Long Beach, CA, 1997.

This presentation describes the FAA's weather research program, defines the Product Development Team (PDT) approach to research, and names the nine PDT research areas. They include:

- Airframe icing;
- Real time liquid equivalent snowfall rate, wind speed and direction and temperature data (WSDDM) to airline and airport operators;
- Aviation-related weather data in gridded format (AGFS);
- Convective weather detection;
- Convective weather forecasting;
- Ceiling and visibility;
- Turbulence;
- Model development and enhancement; and
- Runway winds.

4. Hegwood, Julie Anne Yates. *Human Factors in 1988 General Aviation Accidents*. Transportation Research Record No. 1332, Transportation Research Board, Washington, D.C., 1992.

This study, conducted by an Industrial Technology Education student at Indiana State University, examines the role of pilot error in aviation accidents during 1988. The study included 50 random accidents classifying the pilot error as cognitive, social, or situational. The study found that only 10 of the 50 pilots received a weather briefing, eight from a flight service station and two from a television weather broadcast.

5. McKeever, Benjamin, Carl Haas, Jose Weissmann, and Richard Greer. *A Life Cycle Cost-Benefit Model for Road Weather Information Systems*. Preprints, 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1998.

This paper describes a cost-benefit study conducted for the installation of an Roadway Weather Information System (RWIS) on Interstate 10 in TxDOT's Abilene District. The study balances the cost of installing the weather monitoring and forecasting system with the savings resulting from more efficient winter maintenance procedures and reduced winter accident rates. The study concludes the RWIS is very cost effective.

6. Adams, Michael J., and Thomas J. Martinelli. *Innovative Uses of RWIS Technologies in Wisconsin's Winter Maintenance Operations*. Preprints, 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1998.

This paper describes the use of the RWIS in Wisconsin. Weather extremes are significant in this northern state, with snowfall amounts ranging from 40-inches per year to as much as 150-inches per year. The benefits of the RWIS to the state are dramatic given the extreme weather conditions. In the past 12 years the system has grown from one sensor to more than 50 remote

processing units (RPU's) and 85 vehicle mounted infrared pavement temperature sensors. Additionally, the state contracted a full time forecaster and the use of a satellite communication system to deliver weather data to users scattered across the state. The system includes a training program to teach users how to effectively use the available weather data.

7. Pisano, Paul, and Gary G. Nelson. *Weather Information for Surface Transportation*. Preprints, 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1998.

This report is based on a White Paper produced by a cross-agency group initiated under the rural intelligent transportation system (ITS) program of the U.S. Department of Transportation. It discusses creating a dialogue between the meteorological and transportation communities to provide data needed by each user. It suggests the inter-agency and intermodal infrastructure sharing to provide for continuing improvements in weather information not funded by the transportation sector. Even where there are direct transportation investments (e.g., RWIS), agencies can enhance effectiveness by merging the sensor information with the larger weather information system.

8. Eaton, L. Scott, Margaret A. Lin, and Cheryl Lynn. *Assessment of Sources of Weather Data for Selected Virginia State Agencies*. Preprints, 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1998.

This paper, concerning the uses of weather data in Virginia, is extremely pertinent to this Texas project. The objectives are very similar to those researchers are attempting in Texas. The Virginia objectives included:

- identify sources of weather data;
- identify weather information users; and
- determine the sources, uses, distribution, and cost of obtaining weather information.

The authors found that advances in Internet technology will minimize the need for contracting with private vendors for daily or long-term weather data.

9. Boselly, S. Edward, III, G. Stanley Doore, Dr. John E. Thornes, Dr. Cyrus Ulberg, and Donald D. Ernse, P.E. *Road Weather Information Systems, Volume 1: Research Report*. Strategic Highway Research Program, National Academy of Sciences, Washington, D.C., 1993.

This report provides an overview of roadway snow and ice control practices, the types of road weather information currently available, the methods for communicating road weather information, and the uses for this information in roadway snow and ice control. The report presents the results of field tests conducted to answer questions on the location of RWIS, and discusses the methodology used in determining possible cost-reduction ranges for RWIS

implementation to support roadway snow and ice control. The report also presents conclusions and recommendations for RWIS use by state and local highway maintenance agencies to support snow and ice control activities.

10. Boselly, S. Edward, III, G. Stanley Doore, and Donald D. Ernst, P.E. *Road Weather Information Systems, Volume 2: Implementation Guide*. Strategic Highway Research Program, National Academy of Sciences, Washington, D.C., 1993.

The Strategic Highway Research Program sponsored research into the use of RWIS for highway snow and ice control. The research indicated that using RWIS technologies can improve the efficiency and effectiveness, as well as reduce the costs of highway winter maintenance practices. This Volume 2 implementation guide supplements Volume 1, which documents the research. Volume 2 describes available RWIS technologies, sources of weather information, communication requirements, guidance on siting RWIS that includes a sample Request for Proposals for obtaining the necessary equipment and services.

11. National Oceanic and Atmospheric Administration. *National Environmental Satellite, Data, and Information Service, 1995*. U.S. Department of Commerce, Washington, D.C.

A brief, but colorful, report of work conducted by the National Environmental Satellite, Data, and Information Service (NESDIS), particularly during the year 1995. The primary activity of NESDIS is managing the data collected using the two GOES and the Polar Orbiting Operational Environmental Satellite. To manage this mountain of data pertinent to meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences, NESDIS organized several specialized units. They include:

- Office of Satellite Data Processing and Distribution (OSDPD)
- Office of Satellite Operations (OSO)
- Office of Research and Applications (ORA)
- Office of Systems Development (OSD)
- National Climatic Data Center (NCDC)
- National Oceanographic Data Center (NODC)
- National Geophysical Data Center (NGDC)

12. Holt, Francis C., ed. *GOES Products and Services Catalog*. National Environmental Satellite, Data, and Information Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, D.C., August 1996.

This catalog describes the products and services available from the new generation of GOES. The catalog defines a product or service as any item routinely produced. The catalog presents an example of each product along with a short description of the elements or processing steps, frequency, accuracy, and availability. It also includes references to technical documents that provide more details or scientific algorithms.

13. NEXRAD Panel, National Weather Service Modernization Committee. *Assessment of NEXRAD Coverage and Associated Weather Services*. National Research Council, National Oceanic and Atmospheric Administration, Washington, D.C., 1995.

This report, prepared in response to a request from the Secretary of Commerce, assesses the adequacy of NEXRAD coverage. Plans call for the installation of 138 NEXRAD systems—116 operated by the NWS and 22 operated by the Department of Defense—along with 118 associated Weather Forecast Offices (WFO's), 112 being located within the contiguous U.S. Supplementary to the NEXRAD's are the orbiting ASOS satellites, and the AWIPS. The panel found there is little, if any, deterioration in the quality of weather service products that would result from these changes.

PERIODICALS

1. Proctor, Paul, "New Advisory System For Uncontrolled Field." *Aviation Week and Space Technology* (June 30, 1997): 38.

Based on the tracking function of the Transponder Landing System, built by Advanced Navigation and Positioning Corp., the Automated Airport Advisory Service (AAAS) detects and tracks the position of aircraft operating a transponder within 10 miles of a host airport and up to 3,000 ft. above the airport. The aircraft's location is then integrated into voice-synthesized radio advisories and broadcast on the airport's common traffic advisory frequency.

2. Horne, Thomas A., et al., "Navigating Summer's Worst." *AOPA Pilot* (June 1997): 48-72.

This sequence of articles describes some modern sources of weather information and how pilots can obtain and use the information. Of special interest is the online weather data available via the AOPA's web page. This service is a joint effort between the AOPA and American Weather Concepts, a new company located near Pittsburgh. Some of the service is free, at least for AOPA members, while there is a charge for other, more elaborate elements of the service.

3. "GTE DUATS Flyer." *AOPA Pilot*, Newsletters 1 through 18.

AOPA Pilot magazine published these Digital User Access Terminal System (DUATS) newsletters periodically during 1996, 1997 and 1998. However, because of contract changes, newsletters published before Oct. 1, 1996, are obsolete and pilots should not use them. The majority of the newsletters outline procedures for operating the CIRRUS software, including procedures for preparing flight logs, file flight plans, and obtaining weather maps, in addition to obtaining conventional textual weather information.