NWS PROGRAM SURVEY: Continuing Advances in Technology

National Weather Service
Office of Meteorology

June 1988

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
Silver Spring, Md. 20910

AUG 8 1988 W/OM22:JAK

MEMORANDUM FOR: W - Elbert W. Friday, Jr.

FROM: W/OM - James L. Rasmussen

SUBJECT: NWS Program Survey

The attached document is the result of a continuing attempt to keep us all abreast of the latest technological advances and plans of the National Weather Service (NWS). It brings together descriptions of the many diverse elements of the NWS' communication, observation, and display systems, as well as major experiments in which the NWS is a participant.

While this report is intended to be comprehensive, it is inevitable in such an undertaking that some program gets overlooked and that minor errors creep in. Also, as the summary indicates, this document is frozen in time (approximately June 1988). With the fast pace of technological change, it is likely that some of the document is already becoming outdated.

Nevertheless, I hope this gives a good perspective on where the NWS stands technologically in the late 1980's, and where it is heading in the 1990's.

Attachment

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1.0 INTRODUCTION

NWS has begun a far-reaching modernization which is directed at completion for the early 1990s. NWS products and services -- indeed the NWS itself -- will likely change profoundly as technology enables the improvement in observation and telecommunications. The key to the efficient NWS use of advances in these fields will be the use of computer technology. The revolution in mini- and microcomputers has already enabled NWS to speed up its preparation of warnings and forecasts and to disseminate them more quickly, to the benefit of a growing community of increasingly sophisticated users. At this time also, NWS has the best educated and most competent staff in its history, and so it is well prepared to respond to future challenges.

This report describes the uses of technology in the operations of the National Weather Service (NWS). It has been produced by the NWS Office of Meteorology (OM) with the considerable assistance of many segments of NWS -- see Section 8. Like its two predecessors, it will quickly become out of date in the sense of specific dates and schedules. Yet, this report should be a valuable source of general information on NWS operations and programs.

The information contained in this report is current as of mid 1988. A mention of a specific company or commercial product does not constitute or imply endorsement by NWS.

1.1 Previous Versions of this Report

National Weather Service, 1981. "Technology Assessment for the 1980's and Projections for the 1990's." Office of Meteorology, Silver Spring, MD, May 1981. 21pp.

National Weather Service, 1986. "NWS Program Survey: An Inventory of Technological Advances." Office of Meteorology, Silver Spring, MD, May 1986. 42pp.

2.0 ATMOSPHERIC OBSERVATIONS

Measurements of meteorological and hydrological parameters, such as temperature, moisture, pressure, wind, and rainfall, are the basis for production of NWS warnings and forecasts, as well as the cornerstone of climatology. NWS will continue to support programs that provide weather observations, both nationwide and worldwide. In keeping with cost-conscious trends in Government, NWS will seek to increase automation of its observational functions.

2.1 Surface Observations

The NWS surface observation program involves more than 1,200 people and annually consumes over 300 staff years. Automating the observation procedure as much as possible offers a greater opportunity to use personnel more efficiently while taking advantage of advances in technology. This is critical since NWS will require more observational data in coming years as it seeks to focus on subsynoptic scale weather systems, which often may not be adequately detected by current observational networks.

2.1.1 Hydrologic Observing Networks

NWS hydrologists have used observational data from a variety of sources over the years, including: cooperative weather observers from NWS and the Department of Agriculture; gauging sites of NWS, U.S. Geological Survey (USGS), and Corps of Engineers (COE); surface aviation reports from NWS, Federal Aviation Administration (FAA) and Department of Defense (DOD); and the Automatic Hydrologic Observing Systems (AHOS), in which some 500 stations report river and rainfall observations via land line or satellite directly to NWS offices. Recently, automated hydrometeorological observing systems (LFWS; section 2.1.2) owned and operated by local, state and other Federal Government agencies have provided data to NWS field sites. While the ever-increasing amounts of data have been quite useful to NWS, there have been several areas of concern: the data have been in different formats; data bases have been located in widely dispersed sites; and the functions of the instrument sensors often have not included the provision of data exclusively for hydrometeorological purposes. NWS, in its attempts to modernize and streamline its operations, is involved in a number of efforts to address these concerns.

NWS and COE have been the primary developers of the Standard Hydrologic Exchange Format (SHEF), a unifying data coding and exchange method for providing a flexible means of automatically distributing data and information among the many agencies that use hydrometeorological data. The unique SHEF format has also alleviated the problem of varied data formats from the many sources of hydrometeorological data used by NWS.

One of the vital components of the current hydrometeorological observing systems for a long time has been cooperative observer networks (Section 2.1.3). Despite their importance, the cooperative networks have had several major deficiencies. For example, most of the observers report only when rainfall during the previous hydrologic day (1200 UTC to 1200 UTC) has exceeded 0.5 inches. Another deficiency is that the reports are telephoned into a service hydrologist or hydrologist-technician at a WSFO, a process that is time-consuming, error-prone, and not cost-effective. Some of the inefficiency from the data-collection procedure has potentially been removed by demonstration programs in which the observers enter their data via touch-telephone into a minicomputer. Other automation efforts are being led by Federal and state agencies which operate hydrologic observing networks, two of which are COE and USGS. Many of these agencies' gauges report hourly data through the GOES Data Communications System (DCS) to ground stations which collect and relay the data every three hours. To improve the timeliness of automated reports, a program is under way to make observational data available through emergency channels from the satellite, which will include event- or criterion-generated reports in real time.

Automated NWS hydrometeorological stations such as AHOS have until recently been designed to provide data only at six-hour intervals (synoptic times) because NWS hydrological and meteorological operations have historically been focused upon the use of observations taken at those times. As a result of these time requirements, communications problems have often developed in part because of the volume of data flowing to NWS River Forecast Centers (RFC) at synoptic times; so much data were received that several hours were needed to receive and process the data. This situation became increasingly less acceptable to NWS, particularly during major flood events when up-to-date information must be relayed to RFCs without delay. Recent developments in NWS hydrometeorological sensors and in communications methods are leading to establishment of networks of event-based, self-reporting sensors and communications channels. These systems ease the communications loads at RFCs because only new information is sent from the gauges; the required synoptic six-hourly data for forecast model input can be interpolated with sufficient resolution from the event-generated observations. An added benefit of these systems is that the current site status is always known, within small time increments.

The current network of NWS and FAA synoptic and basic weather observing stations is another major source of hydrometeorological information. Synoptic data are included in the basic observation every three hours. The Automated Surface Observation System (ASOS), section 2.1.5) will enable increasing amounts of automated observational data to be disseminated every hour via AFOS. These data will also be available to RFCs in SHEF every 15 minutes, with instantaneous values available at all times on a callup basis. The ASOS network will be backed up by two networks having a combined size of about four times the current surface observational network. The larger of the two networks will be run by FAA; the other will be operated by DOD. FAA has agreed to supply backup data of the same frequency and quality as from the ASOS network. DOD will supply their data at the synoptic times for RFC forecast models, at minimum.

2.1.2 Local Flood Warning Systems (LFWS)

Local flood warning system (LFWS) is the general designator for a set of procedures developed by a community or other local government to monitor stream flow and to propose actions for protecting lives and property in the event of floods. Specifically, an LFWS consists of a community or local system comprised of: volunteers; rainfall, river, and other hydrologic gauges; hydrologic models; a communications network; and a community flood coordinator responsible for issuing warnings. LFWSs may be manual or automated. About 900 LFWSs were operating as of late 1987, in addition to the

3,100 communities for which NWS provides specific flood warning and forecast services. But that leaves some 16,000 communities that are flood prone, according to the Federal Emergency Management Agency (FEMA); NWS cannot provide specialized services for so many communities. NWS has hydrometeorological forecasting and technological expertise and has committed itself to providing, as its resources permit, technical and forecast assistance to communities that seek to establish LFWSs.

2.1.2.1 Manual LFWSs

Most LFWSs are of this type, which consists of a local data collection system, a community flood coordinator, a simple-to-use flood forecast procedure, a communications network, and an emergency action plan. The data sensors may range from rain and river gauges read by volunteers to automatic rainfall and stream gauges in remote or sparsely settled areas. Such an LFWS may be as elementary as a single gauging site for a small basin and serving a single town. But the characteristic of these manual systems is that virtually all of the warning and forecast procedures are done by people.

2.1.2.2 Automated LFWSs

Recent technological advances and decreasing costs in computerized systems have sparked a steady growth in automated LFWSs. Three systems have evolved so far.

Flash Flood Alarm Systems (FFAS): FFASs consist of water level sensors connected to an alarm device located at a community agency with 24-hour operation. Water levels exceeding preset values trigger the alarm device is located upstream of the community. The lead-time warning is given when the alarm sensor is set to a predetermined water level. Communication between the gauge and the base station is by dedicated land line or radio. FFASs may be part of both manual and automated LFWSs.

Automated Local Evaluation in Real Time (ALERT): The ALERT system was developed by the California-Nevada RFC in Sacramento, CA, and consists of automated event-reporting river and precipitation gauges, automated data-collection and processing equipment, a hydrologic model, hydrometeorological analysis, and software for processing, communications and display. The precipitation gauge are modular, self-contained units. A tipping bucket mechanism causes transmission of a radio signal containing the station identifier and an accumulated precipitation value when 1 millimeter of precipitation is detected. The river gauge transmits preselected incremental changes in river elevation, using the same electronics as in the precipitation gauge. Both gauges are powered by self-contained batteries. Data collection and processing hardware consist of a radio receiver to collect event-reported radio signals, and a dedicated microcomputer system. Radio transmissions from the gauge locations to the local agency are line-of-sight. The data collection systems operate continuously in a fully automatic mode, receiving data and processing information for display to the user, including precipitation maps. The Sacramento streamflow simulation model can provide updated streamflow forecasts every twelve minutes.

Integrated Flood Observing and Warning Systems (IFLOWS): NWS, in cooperation with the Appalachia Regional Commission, the Tennessee Valley Authority, and the States of Kentucky, Virginia, Pennsylvania, West Virginia, and Tennessee, has implemented a prototype IFLOWS. This system combines event-reporting sensors, data and voice communications, and minicomputer technology to each county in a 100-county region covering the states noted. Data, forecasts, and warning products are distributed to state and country authorities responsible for the provision of emergency services to people in flood-threatened areas. NWS offices are directly linked to IFLOWS. The sensors trigger the transmission of radio signals that include the station identifiers and values of the monitored parameters. The sensors and transmitter are battery-powered. Radio transmissions from the sensors are line-of-sight to receivers which relay the information via microwave radio to the dedicated central processing minicomputer. The counties and communities can receive warnings, forecasts, and data over this same communications system. IFLOWS operates continuously to monitor local conditions for the counties and communities and for NWS offices in the IFLOWS region.

2.1.3 NWS Cooperative Observer Networks

More than 5,000 cooperative observers send precipitation and streamflow reports to NWS offices by phone. Some report daily; others report only when certain criteria are met. In addition, some of these observers contribute to special programs such as severe weather spotters and agricultural networks, reporting to NWS offices when criteria for these programs are invoked. Additional reports would be desirable, especially during nighttime hours; but there is a problem with the cooperative reporting system as it exists now. The system is time-consuming and labor-intensive since most of the reports have to be taken over the phone by NWS personnel. This situation can be critical during severe weather, just when timely information is most needed.

An experimental program, Remote Observation System Automation (ROSA), has been developed in an attempt to expedite the flow of data. ROSA is operated in the NWS Central Region with four minicomputers; about 1,200 to 2,000 criteria-initiated observations are sent daily by some 750 observers. ROSA is based on experience with agricultural observer networks. It is used for communicating cooperative observations to the RFC via AFOS. The observer enters the data into the memory of an encoder; the observation is verified and sent to the ROSA microcomputer for formatting and transmission to AFOS. NWS Southern Region has implemented in several states a system which is similar to ROSA, called Automated Tone Dial Data Collection System (ATDDCS).

2.1.4 Snow Survey Using Passive Sensors

A current operational NWS program uses aircraft-borne sensors to measure terrestrial gamma radiation, which is attenuated by water mass in snow and by soil moisture in the upper 20 cm. This program operates over 1,078 flight lines, covering 16 states between Maine and Montana, as well as 5 Canadian provinces during the fall and winter; the area scanned covers river basins outside the operational field area subject to snowmelt flood problems. Snow water equivalent and soil moisture data are available to the public, and the program is coordinated among several U.S. and Canadian agencies.

2.1.5 Automation of Surface Observations Program (ASOP)

Several automated observing systems have seen fairly widespread though limited use in the NWS for a number of years. AHOS (section 2.1.1) is one, and another is a series of Automatic Meteorological Observing Stations (AMOS) sites, which provide hourly observations of temperature, pressure, and wind primarily for surface aviation observations. Other parameters necessary for aviation interests, such as ceiling, visibility, occurrence and type of precipitation, and remarks, must be added manually to AMOS reports. About 50 AMOS sites and 50 Remote AMOS (RAMOS) sites are operational.

Recent advances in sensor and microprocessor technology have made it possible to automate the surface observation more readily. To seize the opportunity presented by these advances, NWS has established the Automation of Surface Observations Program (ASOP). Its goal is to implement ASOS at all NWS primary observing stations.

2.1.5.1 Automated Surface Observing System (ASOS)

With the advent of new sensor and computer technology over the past decade, the feasibility of automating the nation's surface weather observations is becoming a reality. NWS has assumed the lead role in the purchase of up to 1,000 ASOS units which will be used by NWS and FAA. To meet the common requirements of both NWS and FAA, NWS will design, procure, install, operate, and maintain ASOS for both agencies.

ASOS is a key element in the NWS plan for modernization and field restructuring. It will allow NWS to meet increasing demands for airport weather observations without adding staff. NWS plans to implement ASOS at about 250 of its primary observing stations, which are mostly WSO and WSFO locations.

As part of its National Air Space modernization, FAA has a firm requirement for at least 537 ASOSs and a potential requirement for an additional 204 systems. Two operational applications are planned:

- A non-towered or small-airport application -- the intent of this program is to provide ASOS at small, general-aviation airports that have approved instrument approaches but are currently without weather observations. FAA has identified an urgent need for ASOS at 233 such airports; installation at another 204 small airports is possible.

- A towered or large-airport application -- the intent of the towered program is to provide weather observations for 304 airports at which air traffic control facilities or Flight Service Stations (FSS) currently take weather observations.

ASOS will be procured under a two-phase approach which will require competitive solicitations. The initial request for proposals was released in June 1987. After evaluations and negotiations, two or more awards will be made in CY 88 for the first phase design and fabrication of four pre-production systems by each manufacturer.

In the second phase (the production phase), the successful first-phase vendors will compete for the second contract. This will cover the purchase of 36 limited-production systems and subsequently full-scale production of up to 1,000 systems. The second phase is expected to cover a period of five or six years for production and installation. Selection of one vendor to produce all production units is expected in early CY 90, with the first systems to become operational in the fall of 1990.

The implementation schedule calls for the initial 233 FAA small airport systems to be in service by late 1992. All remaining FAA systems will be installed by the mid 1990s. NWS installations are scheduled to begin in 1990 at sites for the Modernization and Restructuring Demonstration (MARD) in the Central Region and to be completed nationwide by late 1993.

A primary benefit of the joint FAA/NWS ASOS program will be the significant improvement in overall national coverage; this in turn will contribute to improved aviation safety and to better public warnings and forecasts by providing observations 24 hours a day, producing better and standardized observations of visibility and sky condition, providing a continuous weather watch and rapid alert of significant weather changes, and allowing for remote maintenance monitoring.

ASOS will automate the observing process, including measurement of weather elements, data processing, display, communication, and archiving functions. It will provide accurate weather information for weather forecasters, pilots, air traffic personnel, and others. ASOS is to be a flexible and modular system capable of being displayed in a variety of configurations and operated with or without the attendance of an observer. Unattended, it will automatically collect, process, ensure the quality of, format, display, archive, and transmit the weather elements required for a surface weather observation. ASOS will also accept inputs from human observers who may override or add information to the automatically generated observation. Because of critical applications in support of aviation operations, ASOS will have considerable built-in quality control features.

NWS, FAA, and components of DOD have interdependent observing programs which nonetheless need to be coordinated. The Joint Automated Weather Observing Program (JAWOP) was established to coordinate observing policy, sensor development and implementation planning among the agencies. Coordination of JAWOP efforts are done by the JAWOP Council, which is chaired by the Federal Coordinator for Meteorology and is comprised of policy level representatives from each participating agency. It addresses such issues as program scope, agency requirements, resource commitments, and agency support to the joint program. The Council provides oversight and policy guidance to assure that the interests of each department are addressed. A JAWOP Action Group has been established to implement the guidance and direction set by the Council.

2.1.5.2 Kansas Pilot Project (KaPP)

The Kansas Pilot Project is an ongoing effort involving prototype ASOS installed at six primary NWS observing locations in Kansas. The sites, some operating with and some without augmentation by observers, were instrumented in mid-1985 and have been operating in parallel to the conventional manual observing operation. KaPP has been especially useful in uncovering unanticipated sensor deficiencies and identifying operational issues that must be resolved to fully benefit from large-scale implementation of automated systems. The prototype systems will continue to operate in Kansas to evaluate new sensor technology and to evaluate contract augmentation procedures.

2.1.5.3 Climatic Test Beds

In this program, ASOS systems are operating in widely differing climatic regimes. Its purpose is to uncover weather-related problems associated with sensors or with NWS-developed algorithms. Test bed sites include Richmond, VA, Fairbanks, AK, and San Francisco, CA.

2.1.6 In-Situ Coastal and Marine Observations

Synoptic-scale weather forecasting requires observational data from all regions of the globe. However, it has historically been difficult to receive weather information from the 72 percent of the planet covered by the the oceans. With the assistance of automation, cooperative programs, and satellites, steps are being taken to fill these "silent areas" so that weather forecasting on a worldwide basis may be more accurate. In this section, several programs conducted or assisted by NWS are described in which efforts are made to provide improved weather observations over the oceans.

2.1.6.1 Ship Observations

Until the 1970s, commercial ships were virtually the only source of weather observations on the high seas. Ship reports are still an important element of marine weather analysis and forecasting; their weather and oceanographic observations have come to play a large role in environmental monitoring and climatology. In addition, ship data provide ground truth for observational programs that depend on automated or satellite sensors. NWS will continue to require ship reports for all its marine warning and forecast programs.

The international Voluntary Observing Ship (VOS) program, using the general structure and the observational codes recommended by the World Meteorological Organization (WMO), counts more than 1,800 participating ships from 54 countries; the U.S. is the largest free-world participator. Worldwide, the VOS produces over 100,000 surface synoptic observations each month. VOS vessels report the standard meteorological parameters; some also record oceanographic parameters such as subsurface temperature, oxygen content, salinity, and ocean-current data, using a variety of conventional and experimental devices. The ship reports are communicated to collection centers, and ultimately to the National Meteorological Center (NMC), by a wide spectrum of methods ranging from ancient to modern. Although future emphasis will be on technological improvements to communication, it is not unreasonable to expect this wide variety of communications modes to continue. These modes include: Morse code; voice transmissions on radio, including observations in synoptic code and unformatted, plain-language MArine REPorts (MAREP); Simplex Teletype Over Radio (SITOR); the Remote Entry Alphanumeric Device (READ), which prompts the observer and transmits by radio; the Shipboard Environmental Acquisition System (SEAS), which prompts the observer, prepares meteorological and bathymetric information, and sends these data by GOES satellite; and the INternational MARitime SATellite program (INMARSAT).

2.1.6.2 Deep Ocean Moored Buoys (DOMB)

A system of 33 DOMBs reports wind, pressure, air temperature, sea-surface temperature, and wave spectra in areas seaward of the continental shelf in the Atlantic and Pacific Oceans and the Gulf of Mexico. Eight more DOMBs operate in the Great Lakes. This system began with the experimental buoy program of the early 1970s in combination with other existing and planned marine data systems, and it represents a sizable contribution to NWS warning and forecast services within the U.S. 200-mile economic zone. DOMB observations are part of the database of the WMO's world climate programs. The importance of ground truth for observational programs that depend on automated or satellite sensors, and the need for subsurface oceanic data, will probably necessitate a continued program of DOMBs, particularly to complement ship and satellite data.

2.1.6.3 Coastal Marine Automation Network (C-MAN)

NWS uses marine reports from 172 U.S. Coast Guard stations, which range from fully automated stations to manned locations. The data flow through a high-speed collection network to NWS, which disseminates the reports as collectives via AFOS. Coast Guard stations have provided weather observations to NWS for decades; the Coast Guard has allowed NWS to install automated observing systems at its sites. NWS and the NOAA Data Buoy Center (NDBC) developed the C-MAN program to install sensors, payloads, and satellite communications equipment similar to the instrumentation on ocean buoys at about 100 coastal headland stations and 8 Large Navigational Buoys (LNB, former lightships). Thirty-nine automated headland sites plus the LNBs are now operational; automation of the remaining 66 sites will depend on the outcome of future budget initiatives.

2.1.6.4 Offshore Platforms

In addition to C-MAN sites, NWS is equipping a number of offshore platforms (some government owned) with automated observing devices. Negotiations with the petroleum industry in 1979 led to the organization of the Gulf Offshore Weather Observing Network (GOWON) off the Louisiana and Texas coasts. Data from GOWON are collected by NWS via several computer interfaces from the oil companies. The GOWON has greatly improved NWS's ability to monitor the weather and to produce warnings and forecasts in the northern Gulf of Mexico. GOWON sites are furnished with personnel, equipment and maintenance by the individual companies. The success of GOWON has led to the development of a network of buoys, platforms, and island stations in the Bering and Chukchi Seas west of Alaska. Very recent negotiations with Mexico have led to efforts to get observations from Mexican platforms in the Bay of Campeche and along the Gulf and Pacific coasts of Mexico.

2.1.6.5 Drifting Buoys

A drifting buoy is an inexpensive device that provides reliable wind, air pressure, air temperature, sea surface and subsurface temperature, and hydrostatic pressure to a depth of 600 meters, as well as ocean-current data. It is ideal for collecting data from ocean areas not regularly transited by ships and unfeasible for a fixed-buoy network. Drifting buoys have proved their utility during several research and forecasting activities beginning with the First GARP Global Experiment (FGGE) in the late 1970s, as well as operational deployments in the subtropical Atlantic and Pacific Oceans for the Tropical Ocean Global Atmosphere (TOGA) Experiment. A grid network of 40 operating drifting buoys has been maintained in the oceans of the Southern Hemisphere since 1984 and is expected to be maintained for the duration of TOGA, through 1994. Drifting buoys have also been playing a very important role in providing valuable data from hurricanes approaching land.

A drifting buoy is designed to report data for one to two years via polar-orbiting satellites. Drifting buoys figure prominently in the future NWS marine observational network because of their reliability and cost. Special efforts are being made to enhance drifting buoy deployments in the North Atlantic to support the WMO's Operational World Weather Watch System Evaluation of the North Atlantic (OWSE-NA) program in FY 88 and FY 89, as ocean weather ships begin to be phased out.

2.1.7 Surface-based Lightning Detection Systems

Radar and satellite observations can indicate areas of probable thunderstorm activity. But beyond the likelihood that a thunderstorm is occuring somewhere, no information is available from these sources concerning the amount of electrical activity in a thunderstorm. Surface airways observers attempt to describe the degree of electrical activity when a thunderstorm is near the observing site; this information is useful to interests in the immediate area of the observation at the time. In recent years, NWS has made a concerted effort to determine the areal extent, distribution, frequency, and intensity of electrical activity in thunderstorms, and to attempt to evaluate the utility of this information in the NWS mission.

NWS efforts at lightning location methods date from the early 1960s, using radio devices to locate static electricity discharged by lightning strokes (sferics). Since 1977, the U.S. Bureau of Land Management (BLM) has operated an Automatic Lightning Detection System (ALDS) in the western United States. The ALDS was installed for BLM and other land management agencies to detect lightning-caused wildfires; but NWS has been able to obtain the lightning stroke data on an experimental basis for its forecast operations. The ALDS network consists of 12 position analyzers and about 30 direction finders, with an effective range of 400 km. Virtually the entire western U.S. is covered by this network. The direction finders observe the direction of the lightning stroke and the magnitude of its electromagnetic signal; they perform waveform matching to determine if a stroke was a cloud-to-ground or cloud-to-cloud stroke. The lightning stroke's location is computed by triangulation using the received direction and magnitude from two direction finders. Real-time data (every half hour) and accumulated data (every 24 hours) are sent from the Boise Interagency Fire Center in Boise, ID, to NWS Western Region (WR) Headquarters in Salt Lake City, UT. The processed data are then sent to the WR AFOS loop. Data consist of mapped stroke location and intensity; the intensity is available in both digital and contoured forms. These data have since 1983 been distributed to all WR WSFOs and WSOs, and they may be accessed throughout the AFOS network.

The ALDS data have been useful to NWS in a number of ways. In the WR, continuous areal radar coverage is not available because of the mountains; ALDS has enabled forecasters to locate areas of thunderstorms in these areas. ALDS has helped forecasters to distinguish thunderstorms from non-thunderstorm clouds and to detect thunderstorms embedded within dense cloud masses. Ongoing research studies are attempting to relate lightning frequency to rainfall rate.

A network similar to the BLM network has been established in the eastern U.S. Its coverage extends from Florida through New York and most of New England. The 30 direction finders in the network are controlled by a computer at the State University of New York at Albany (SUNYA). Data from this network are distributed to NWS field sites from WSFO Albany via the Eastern Region AFOS loop. NWS has access to other large, privately developed networks of lightning detection systems in the Gulf Coastal and central states. Networks of lightning detection sensors operate in Alaska and Canada, as well as the western U.S. Smaller networks operate experimentally in Colorado, Oklahoma, Florida, and in other locations. NWS is exploring plans to work with BLM, DOD, FAA, and other agencies to establish a national network of lightning detection systems. A major step was taken by Federal agencies in 1987 to establish an experimental national network in cooperation with SUNYA. The experiment centers around a proposal by SUNYA to collect and merge data from their East Coast network along with data from the BLM and National Severe Storm Laboratory (NSSL) networks. Agencies will be able to access data at the agencies' cost for evaluation purposes during the course of the three-year effort.

2.2 Upper-Air Observations

The rawinsonde network is the foundation of NWS upper-air analyses and forecasts. Observations from automatic remote sensors -- profilers and satellites -- will be increasingly useful with time.

2.2.1 Conventional Atmospheric Soundings

Upper-air observations over land, obtained by balloon-borne radiosondes having temperature, pressure, and relative humidity sensors, remain the foundation of NWS basic meteorological analyses and numerical weather prediction. This network of 114 units, which dates from the 1940s and 1950s, provides the ground truth for other types of sounders such as profilers and satellite sensors. Its importance will be undiminished, but in the interest of reducing errors and cost, the network will become increasingly automated.

The Automatic Radio Theodolite (ART) program is designed to upgrade and automate current upper-air tracking systems. It has replaced outdated subassemblies with solid-state modules and other equipment to allow automatic operation. Full automation has resulted from computer software that recognizes the meteorological data transmitted by a time-commutated radiosonde. ART hardware has been installed at 89 upper-air stations, and ART software is operational at 82 sites.

2.2.2 Automated Shipboard Aerological Program (ASAP)

ASAP is an evolutionary program dating from the mobile weather ship program and international experiments in the 1960s which used ship-borne radiosonde stations extensively. An operational impetus for ASAP was the elimination of the stationary observation ship PAPA in the North Pacific Ocean, without whose data the forecasting of rapidly intensifying storms over the North Pacific became difficult. The current ASAP is a joint U.S.-Canadian effort to produce upper-air information over data-sparse areas like the North Pacific Ocean. The program relies on ships of opportunity that travel the shipping lanes between Japan and the west coast of North America and is based on successful test programs in the North Atlantic in cooperation with the United Kingdom. The individual ASAP system consists of the upper-air sounding system, the satellite transmitter and the work area in one of two compartments of a structure on the ship's deck, and the launcher and helium supply in the other compartment. It operates on the ship's electrical system independently of the normal ship activity. With minimum training, a person is able to launch an instrumented balloon twice a day and to enter the surface observational data into the computer. The upper-air observation is then automatically processed and transmitted via the Global Telecommunications System with no further human involvement. The ASAP data will serve as valuable ground truth for other meteorological information such as aircraft and satellite soundings.

ASAP started with two shipboard units in late 1985. NWS furnishes personnel, and Canada provides maintenance and expendables. NWS Headquarters is involved with WMO in coordinating North American efforts with those of other member nations with the goal of standardizing operations. Further plans call for using current operations as a basis for determining costs of an expanded ASAP program. Areas that lend themselves to future ASAP coverage include routes between the U.S. west coast and Alaska, and routes to the Panama Canal, Hawaii, and points in the Far East.

2.2.3 Atmospheric Profilers

NOAA's Environmental Research Laboratories (ERL) have since the late 1970s investigated the use of ground-based sensing techniques to determine vertical variations of temperature, moisture, and wind. Their research led to the development of surface-based upward pointing sounders known as profilers. A number of prototype profilers have been operating in parts of Colorado since 1980 as part of the ERL Program for Regional Observing and Forecasting Services (PROFS), which cooperates with NWS and other agencies in developing new observing and forecasting systems. Two types of profilers are under development: thermodynamic and wind profilers.

The thermodynamic, or radiometric, profiler is a microwave radiometer that senses air temperature and dew point in discrete atmospheric layers. The wind profiler is a multiple-beam Doppler radar system that senses turbulent layers in the atmosphere and converts shifts in turbulent eddies to wind vectors. Both systems produce data hourly, and the current ERL research wind profilers can produce data every 12 minutes. Thermodynamic profilers are less advanced in their development than wind profilers, but both systems have shown considerable potential to improve NWS warnings, forecasts, and services. Examples of these possibilities include the use of thermodynamic and wind profiler data to produce updates to a conventional sounding, and the use of a triangular array of wind profilers to calculate vorticity, divergence, and vertical velocity at the centroid of a triangle. Research has suggested that thermodynamic profiler data below about 600 mb can be combined with geostationary satellite sounding data above 600 mb with enough accuracy to be potentially useful for highly sophisticated monitoring of the atmosphere, with increased space and time resolution compared to the current radiosonde network. However, thermodynamic profilers as currently designed suffer a serious attenuation of the radiometer signal when rain falls at a rate of more than 5 mm hr^{-1}.

The Wind Profiler Demonstration Project (WPDP, section 6.3) will operate an experimental network of 30 wind profilers in the Midwest beginning 1989 and continuing through 1992. Data from this network, the Wind Profiler Demonstration Network (WPDN), will form the input for mesoscale numerical forecast models which are as yet undeveloped. The WPDN will be used to provide information to NOAA for establishment of a national operational network of wind profilers in the 1990s.

2.2.4 Automated Aircraft Observing and Reporting Systems

Wide-bodied commercial jet aircraft equipped with sophisticated navigation systems have been flying transcontinental and oceanic routes since the late 1960s. Meteorological reports have been sent from these aircraft for many years, but their use has been limited. Only one observation, of wind and temperature, is taken every 900 km. The report is sent by voice radio communication, it is manually processed, and it must be sent on communications circuits to get to meteorological centers. All of these steps contribute to potential errors and untimely reception at the processing centers. Two programs, ASDAR and ACARS, are under way to improve the process of collecting weather reports from aircraft-mounted sensors.

2.2.4.1 Aircraft to Satellite Data Relay (ASDAR)

In the late 1970s, as part of the enlarged observation network for FGGE, the Aircraft to Satellite Data Relay (ASDAR) device was developed to exploit more fully the increased potential for aircraft observations from data-sparse regions. The successful demonstration fielded 15 prototype ASDAR units on aircraft of several international air carriers. The units sample wind, temperature, time and position every 7-1/2 minutes (120 km between observations); a report containing 8 observations is sent every hour to ground stations via geostationary meteorological satellite. ASDAR wind speeds at flight levels are accurate to 3.5 kt, which is comparable to the accuracy of radiosondes; temperatures are accurate to 1C. Thus ASDAR can produce a high-density set of reliable wind and temperature observations to be sent to a meteorological processing center within one or two hours of observation time.

In addition to sampling at flight levels, ASDAR can provide wind and temperature profiles when the aircraft is ascending or descending at airports. An operational ASDAR unit is being developed by a WMO-coordinated consortium of meteorological services and will add the capability of providing turbulence and maximum wind data. International carriers of the consortium members will have units installed. U.S. carriers have no immediate plans for participation, but the State Department will purchase units for installation on the airline of a developing nation whose aircraft will use U.S. airspace. Plans call for at least 13 ASDAR units in operation by the early 1990s.

The principal limitations of the ASDAR system are that the meteorological information is observed primarily at a single level, and profiles are concentrated near major airports. The main advantage is that a substantial deployment of ASDAR units on commercial aircraft can contribute thousands of timely flight-level observations to the global data base from data-sparse land and ocean areas.

2.2.4.2 ARINC Communications Addressing and Reporting System (ACARS)

The ARINC (Aeronautical Radio, Incorporated) Communications Addressing and Reporting System (ACARS) is expected to be the primary means for receiving automated aircraft reports over the U.S. The system is designed essentially as an air-ground data link for passing on operational airline information. However, when augmented with specialized hardware and software, it can be used to collect and transmit meteorological data in a manner similar to ASDAR. Unlike ASDAR, the transmission of data is accomplished through a line-of-sight VHF radio link instead of by satellite. This restricts its coverage to land areas where ground stations are installed and to nearby oceanic areas. At this time, only North America and Australia have ACARS installed; but Europe and parts of the Middle East may follow within two or three years.

ASDAR and ACARS are probably the forerunners of later systems that will be fully integrated into the standard avionics found on new generations of aircraft. By 1995, substantial numbers of wide-bodied aircraft will have aeronautical satellite communications equipment as part of their avionics suite. Many of these aircraft will be automatically reporting basic wind and temperature data through these systems. To ensure that the full data acquisition potential of these and other systems is realized, national meteorological services must make their needs known to those developing the systems and must convince airline management of the value of these data.

2.2.5 Satellite Remote Sensing of the Atmosphere

Meteorological satellites have provided reliable information for more than 25 years. They have become virtually indispensable to the science and practice of meteorology, and future satellites will provide significantly improved information.

NOAA's National Environmental Satellite Data and Information Service (NESDIS) is responsible for the procurement and operation of weather satellites. NWS operations are currently based on having two polar orbiting and two geostationary satellites in orbit. At this time, the NOAA-9 and NOAA-10 polar satellites provide temperature and humidity soundings as well as imagery. Two geostationary satellites, GOES-6 and GOES-7, are available for imagery and sounding data.

NWS operational use of satellite data in forecasting began in the mid-1960s when NMC began to routinely use Applications Technology Satellite (ATS-3) and polar orbiter mosaic imagery to fill in data-sparse portions of synoptic analyses. In 1972 the first Satellite Field Services Station (SFSS) was established at Washington, DC, collocated with the WSFO. It provided the first regular uses of satellite data at field locations, supplying interpretation of weather conditions based on still pictures and animated ATS imagery to the WSFO for the local warning and forecast program. In 1974, three more SFSSs were established: at Miami, FL, collocated with the National Hurricane Center (NHC); at Kansas City, MO, collocated with the National Severe Storms Forecast Center (NSSFC); and at San Francisco, CA, collocated with the San Francisco WSFO. At that time, the SFSSs began to be conduits for GOES satellite imagery sent via high quality telephone lines to all WSFOs within the SFSS area of responsibility, and to a growing number of other users, both in the Federal Government and in the private sector.

All SFSSs rely on electronic forms of data presentation. A video disc system produces up to 24 hours of data in animated loops. Typically, the SFSS uses TV monitors located at the various forecast areas within the collocated NWS facility to display a number of loops as well as the most current image. The SFSS does not transmit loops to users; this capability is available at

WSFOs by means of a Satellite Weather Information System (SWIS; refer to section 4.2) device. Since 1984, SFSSs have been part of NWS. They are being phased out as satellite data have become an integral part of NWS operations.

2.2.5.1 Satellite Imagery

Imagery from satellites continue to be the most important product from the satellites. From the earliest images supplied by TV cameras onboard the Television and InfraRed Ovservation Satellites (TIROS), imaging technology has progressed to its current state as used by the geostationary and polar-orbiting spacecraft of the late 1980s. The GOES satellite sensor is the VISSR Atmospheric Sounder (VAS), which has three operating modes:

- the Visible/Infrared Spin Scan Radiometer (VISSR) mode, which provides hemispheric visible and IR imagery every half-hour and covers smaller areas at more frequent intervals;

- the multispectral imaging (MSI) mode, which can provide visible and up to four simultaneous IR images selected from the 12 IR channels of the VAS; and

- the dwell-sounding (DS) mode, which allows each of the 12 spectral channels to repeatedly scan an area.

In both the MSI and DS modes, an onboard processor is used to control scanning sequences.

The visible and IR images produced every half hour, as well as the water vapor images produced hourly, are processed, sectorized and enhanced at NESDIS's Central Data Distribution Facility (CDDF) in Camp Springs, MD, and are relayed by WSFOs with collocated GOES-TAP communications hubs. Visible and IR imagery produced as often as every five minutes over small areas are sent to NSSFC and NHC, to support continuous monitoring of rapidly developing severe weather or tropical cyclone activity. SWIS (section 4.2) provides imaging capabilities to WSFO operations. VAS Data Utilization Centers (VDUC, section 4.5) have sophisticated imaging capabilities. A VDUC has been installed at NMC. VDUCs for NSSFC and NHC are scheduled to be installed in 1988.

Imagery from NOAA Polar Orbiting Environmental Satellites (POES) has a very important use in NWS National Center and field operations. Since polar orbiters were technologically feasible for many years before geostationary satellites, NWS has been able to use their imagery in many analysis and forecasting areas -- synoptic analysis and tropical cyclone detection, for example -- over virtually the entire globe for as long as weather satellites have been orbiting. Current NOAA polar satellites provide visible and IR imagery by means of their Advanced Very High Resolution Radiometer (AVHRR) sensor, by limited direct readout or to users of GOES imagery served by the SFSSs. Over high-latitude areas such as Alaska, POES imagery is available through the Anchorage SFSS every 90 minutes with each satellite orbit. POES imagery is quite useful for weather monitoring in these areas because of high earth curvature in GOES imagery at great distances from the satellite subpoint. Polar-orbiter imagery and soundings are very important to hydrometeorological services in other parts of the world.

2.2.5.2 Satellite Sounders

Recognizing that critical gaps in atmospheric data were not limited to the earth's surface, NWS in conjunction with NESDIS has been developing and refining satellite-borne sounders to obtain tropospheric measurements of temperature and moisture. Polar-orbiting sounding sensors were developed experimentally in the early 1970s and have become an important part of operational synoptic upper-air analysis and numerical weather prediction (NWP). The POES sounding device onboard the current NOAA satellites is the TIROS Operational Vertical Sounder (TOVS), which consists of the High Resolution Infrared Sounder (HIRS/2), the Microwave Sounding Unit (MSU), and the Stratospheric Sounding Unit (SSU). The TOVS produces atmospheric profiles of temperature from the surface to 10 mb and water vapor and total ozone contents from the surface to about 250 km. The MSU makes it possible to obtain atmospheric temperature profiles under all conditions of cloud cover, complementing the cloud-free sounding capabilities of the HIRS/2. POES sounder data are obtained worldwide for use in global NWP.

Atmospheric sounders for GOES satellites have paralleled the development of geostationary satellite technology. Since 1980, experimental VAS temperature sounding and moisture data have been made available to NMC, NSSFC, and NHC at selected times of the year. The data are used to derive a number of fields for weather monitoring and forecasting. For example, VAS-derived stability fields are used at NSSFC to monitor and forecast severe weather, wind fields are derived at NHC for tropical cyclone environment monitoring, and sounding data are used at NMC for input to the Limited Fine Mesh (LFM) model over the date-sparse North Pacific Ocean. Geostationary sounders of the future will need to overcome problems of cloud contamination to significantly enhance their utility in NWS operations.

VAS soundings cannot be reliably delivered in an operational mode using current GOES satellite sensors. Deployment of GOES I-M with their independent imaging and sounding capabilities will make better operational reliability possible. NWS will continue to focus on using VAS sounding data effectively. There are compelling reasons to pursue refinement of geostationary sounders. Geostationary satellites produce real-time data every half hour or more often, in contrast to data from rawinsondes every 12 hours. Also, the unchanging perspective of geostationary satellites allows constant monitoring over a fixed area.

2.2.5.3 Satellite-Borne Lightning Detectors

Detection of lightning in cloud systems has many uses, as given in section 2.1.7. The concept of lightning detection by remote sensors applied to the satellite perspective offers a possible planetary-scale extension of these uses. Some potential applications of satellite lightning detector data are: examining relationships between lightning activity and storm intensity, and between lightning and tornado occurrence; describing electrical activity in tropical cyclones; and comparing lightning occurrence over oceans to that over land. Currently, a NOAA-National Aeronautics and Space Administration (NASA) team is investigating the suitability and cost of including a lightning detector aboard a GOES satellite by the mid 1990s. A Phase B study, which details costs and engineering impacts, is being carried out by NASA.

2.2.5.4 Remote Sensing of Marine Surface Winds by Satellite

The surface wind over the oceans produces stress that leads to waves and swells, which affect shipping interests. A consistent, reliable definition of the surface wind field is essential in providing useful sea-state information to users. NWS currently uses observations from Voluntary Observing Ships (VOS) and NOAA data buoys to collect data on winds and seas. Obtaining information on sea conditions using polar-orbiting satellites has been a promising idea since the short-lived Sea Satellite (SEASAT) in 1978. SEASAT as well as the research satellite Nimbus-7 had a scatterometer on board which measured the radar return from capillary waves on the ocean surface. It is possible to construct surface wind estimates from this backscatter because capillary waves respond to wind stress. The U.S. is planning to obtain remotely sensed wind, wave, and sea-ice measurements from the European and Japanese polar orbiting satellites (ERS-1, JERS-1) scheduled for launch in the early 1990s. These satellites will carry Synthetic Aperture Radars (SAR) which will provide these measurements under all weather (cloudy or cloud-free) conditions. Similar technology is planned by NASA for the mid to late 1990s through the Earth Orbiting System (EOS) Polar Platform. NWS operations of the 1990s envision the use of these measurements for improving ocean forecast guidance at NMC as well as contributing to a better understanding of air-sea interaction on global and regional scales.

2.2.5.5 Future Plans

Imagery from the GOES satellites will continue to be the product most immediately useful operationally to NWS, but satellite soundings are growing in importance and application to NWS operations. Time sequences, enhancement techniques, wind vectors from paired imagery -- these will continue to be major applications of imagery data. Planned NWS interactive data-processing systems will enhance the use of these and other applications at field forecast sites and National Centers, when used with data from ASOS, radar, and wind profilers. The constant location and perspective of GOES satellites will greatly improve coverage over small-scale areas, which will benefit the study of subsynoptic scale processes. It will also support the construction of a satellite climatic data base.

U.S. satellites are also integral elements of the WMO World Weather Watch (WWW). Other geostationary satellites in the WWW used in NWS operations are Japan's GMS and the European Space Agency's METEOSAT. It is likely that NWS offices with special needs will make use of GMS and METEOSAT data. In addition, NWS offices will be able to use data from ocean satellites of other agencies such as the DOD Defense Meteorological Satellite Project (DMSP) and N-ROSS.

The next series of geostationary meteorological satellites, GOES I-M, is already under development. A contract has been awarded, and the first satellite in the series is expected for deployment in 1990. GOES I-M will offer the following improvements to the current GOES sensor technology: increased IR resolution and number of channels; flexibility of scanning different geographic areas; independent imaging and sounding capability; better navigation; and increased radiometric accuracies and spatial resolution of the sounder. In addition, new technologies such as microwave sounders and lightning detectors (Section 2.2.5.3) are being examined for inclusion on future GOES I-M satellites.

Future POES capabilities are also being developed for the NOAA-K,L,M satellites, scheduled for deployment beginning in late 1993 and continuing through 1996. The most significant improvement in sensor technology will be the Advanced Microwave Sounding Unit (AMSU), which will combine and improve the capabilities of the current MSU and SSU (Section 2.2.5.2). AMSU-produced temperature soundings will be, for up to 30 km altitude, at least as accurate as current POES TOVS sounders (1.5K accuracy for IR [SSU] soundings and 3K for microwave [MSU] soundings). The AMSU's horizontal and vertical sounder resolution will be improved by a factor of about 1.7 over current resolutions. There will be five water vapor channels on the AMSU compared to four on the MSU, including three frequencies around a strong water vapor resonance at 183 GHz for more accurate soundings.

Other more-advanced POES sounders have been proposed that would offer still better resolution and accuracy. These include the Advanced Meteorological Temperature Sounder (AMTS) proposed by NASA's Jet Propulsion Laboratory, the High-resolution Interferometer Sounder (HIS) advanced by NESDIS, and the Conical Atmospheric Tropopause Sounder (CATS) proposed by the United Kingdom Meteorological Office. Technologies required to develop these sounders have not been developed or cannot be tested as yet. Similarly, the NASA Wind Satellite (WINDSAT) project, which calls for the use of lidars on polar satellites for vertical wind profiles, will not be feasible until well into the 1990s.

2.3 Radar

For more than 35 years, weather surveillance radar has been the <u>sine qua non</u> of NWS warning and forecast services, particularly in monitoring severe local storms. Radar will be even more essential in the future as one of several improved technological capabilities in the NWS' increasing focus on small-scale weather systems.

The present NWS basic weather network provides coverage over the 48 states from a variety of NWS, FAA, and DOD radars, some of which (FAA radars) are not primarily for weather detection, and some of which (NWS WSR-57) are more than 25 years old. Newer NWS local warning radars (WSR-74) cover portions of the U.S., mainly east of the Rockies, and they serve to back up the basic network. The oldest NWS and DOD radars have become costly to maintain. Moreover, nationwide scheduled radar observations from network stations are still done manually, although the digital parts of the observations are composited by computer into a national summary chart.

Sustaining the NWS radar network in the pre-NEXRAD time period will be done by a combination of interim measures, plus limited introduction of new technologies. Modifications to current DOD radars will prolong their life by replacing vacuum-tube units with solid-state electronics. The FAA is improving their radars' coverage, resolution, and remoting-and-display capabilities to meet DOT needs; these improvements will upgrade the NWS network coverage as well. NWS interim measures consist of replacing seven of the worst-condition WSR-57s and stockpiling of spare parts, and maintaining computerized radar processing and display equipment at a limited number of sites.

2.3.1 Radar Data Processors (RADAP)

NWS computerized efforts to improve the operational use of radar began with the Digitized Radar Experiment (D/RADEX) in 1971. There are now 10 NWS former D/RADEX sites with RADAP II (RAdar DAta Processor, version II) equipment. The RADAP II equipment consists of the radar system, a minicomputer, and interface devices; the radar system includes the collocated radar, the Digital Video Integrator and Processor (D/VIP), and the Isolation Distribution Equipment (IDE). From observations taken every 10 minutes, RADAP II provides echo intensity and motion, accumulated rainfall, and input to the manually digitized part of the radar observation. Tilt scans, made every 10 minutes if needed, result in gridded display of the location and top height of all echoes' mapped vertically integrated liquid (VIL) water content values, storm structure, and severe-weather probability estimates. RADAP II display capability has been enhanced by the ICRAD (Interactive Color Radar Display), which can produce color graphics on a map background, time looping, product overlays, interactive determination of cell movements, and aids to hourly report generation. RADAP II has demonstrated the feasibility of processing large amounts of radar data in near-real time. It will not be deployed at any additional sites, but it has provided new types of data (VIL, image loops) for operational users and led to valuable information for developing the NEXRAD radar systems.

2.3.2 Remote Display Systems

Current NWS sites without collocated radar, as well as other non-NWS users, are increasingly using electronic display capability. Paper-facsimile machines have been replaced with TV monitors linked by phone line to the radar site; users can also dial into any radar site having the FAA Radar Remote Weather Display System (RRWDS) or private-sector developed display systems. The NWS Radar Information Display (RADID) terminals allow users to dial up RRWDS sites and display up to four images at once, loop up to eight images, and zoom in on nine sectors of the normal plan-position indicator (PPI) display.

A total of 100 RADID terminals have been installed, with two each going to NMC, NHC, and NSSFC, and the rest to RFCs, most WSFOs, and some WSOs with 24-hour warning responsibility. The FAA has installed RRWDS receivers at all Center Weather Service Units (CWSU) and Enroute Flight Advisory Service (EFAS) sites; three WSFOs use RRWDS receivers. WSOs with warning responsibility that did not receive RADIDs are using remote display systems. RADID, RRWDS, and the privately developed display devices are all intended to be interim systems to pave the way for NEXRAD.

2.3.3 Next-Generation Weather Radar (NEXRAD)

The RADAP and RADID techiques and capabilities just described are examples of the features scheduled for inclusion in the Next-Generation Weather Radar (NEXRAD) program. NEXRAD is sponsored by DOC, DOD, and the Department of Transportation (DOT), and will present many kinds of information about hazardous weather to enhance the ability of NWS, DOD, and FAA to support their operational mission requirements. It is expected to be the NWS operational radar system of the 1990s. Among its useful features are its Doppler capability and its processing ability. Experimental Doppler radar use has already demonstrated a sizable list of mesoscale capabilities, including recognition of and alerting the user to tornado-vortex and mesocyclone signatures, and location of areas of horizontal and vertical wind shear. Future algorithms may allow the detection of other small-scale phenomena, such as downbursts, gust fronts, and low altitude wind shear; icing regions; flash-flood producing systems; and hail regions in thunderstorms.

NEXRAD is expected to add significant warning and forecast capabilities beyond those of the current network, such as: improved severe local storm warnings and aircraft safety, from identifying radar signatures and hazardous wind conditions; more effective warnings of all types thanks to increased lead times and better distribution and display of weather information; reduced numbers of false alarms and unwarned situations because of better system reliability and detection capabilities.

About 160 NEXRAD systems are planned for the tri-agency program. NWS will operate 113 and DOD 23 in the 48 contiguous states, with the rest distributed through Alaska, Hawaii, and DOD and FAA installations in other parts of the world. A contract has been signed and operational implementation is set to begin in 1989 and end in 1993.

3.0 COMMUNICATIONS

Advances in communications technology over the last decade have paralleled advances in computer technology. NWS has made extensive use of advances in both fields, so that it is now rare for operational NWS products to be composed and disseminated within NWS by nonautomated and noncomputerized means. The process of composing and transmitting a forecast, for example, has been revolutionized. As late as the mid 1970s, most forecasts as well as warnings, observations, and other products were prepared initially by hand or by typewriter, formatted on paper tape, manually entered for transmission on teletype circuits, and received by users or other NWS offices in the form of paper tape and teletype paper copies. This entire process was labor-intensive and very time-consuming. In the case of warnings, the process could significantly reduce the warning's lead time and hence its potential effectiveness. At this time, the entire process from message composition to receipt by the user has been greatly speeded up with the use of automated and computerized communications facilities.

3.1 Teletypewriter Circuits

NWS use of teletypewriter circuits for communications, data collection and product dissemination within the U.S. has virtually ended. Teletype circuits are still used by NWS as one means of international NWS communications and product dissemination; however, in future years, this use can be expected to decline as satellite communications capabilities are deployed for international meteorological use.

3.2 Automation of Field Operations and Sevices (AFOS)

AFOS, developed in the mid and late 1970s, is currently the primary NWS communications, display, and data distribution system for the contiguous U.S. It has virtually supplanted teletypewriters and facsimile circuits as a means of receiving and sending products at a NWS field office. The AFOS system consists of a nationwide network of minicomputers and medium-speed (2400 baud) communications lines connecting all NWS AFOS-equipped offices. The network is managed from the Systems Monitoring and Coordination Center (SMCC) collocated with the NMC Communications Computer System. SMCC is connected to four regional circuits and, through WSFOs and WSOs, all state distribution circuits. SMCC also is the AFOS communications interface to NMC, other NWS units not considered field offices, and networks for data acquisition and communications external to NWS.

All WSFOs and WSOs in the conterminous U.S. have the AFOS system. Alaska and Pacific Region WSFOs and WSOs are linked within their region by Prime computer-driven circuits operating in a manner similar to AFOS. Each AFOS-equipped office has consoles that include communications interfaces for dissemination. CRT display consoles are used for nonpermanent display of products. Any product in the AFOS system can be displayed at any office. Graphical products with common map backgrounds may be overlaid, and alphanumeric products may be displayed singly or in sequence with other alphanumeric products. Hard (paper) copies of any AFOS product can be made. Products can be archived on discs for permanent record. AFOS has automated the NWS field operations to a considerable degree in the functional areas of data distribution, storage, retrieval, and display; message composition; and external interfaces.

AFOS has already approached its limit for data transmission capabilities. Improvements to AFOS, known as System Z, are planned by 1990. The major enhancement to AFOS will be a front-end processor to allow increased capacity for handling large quantities of information and at the same time free up additional computational resources. Further improvement in transmission will ensue when AFOS System Z is linked to the NOAAPORT (Section 3.3.2) satellite communications system.

3.3 Satellite Communications

3.3.1 GOES Data Collection System (DCS)

The GOES DCS is a communication relay system that uses the GOES transponder to relay transmission from data collection platforms (DCP) to NOAA processing and transmission facilities in Camp Springs and Suitland, MD. The data are sent to field offices via AFOS and remote job entry (RJE) links. The primary NWS use of the GOES DCS is the collection of hydrometeorological and oceanic data; the DCS also is used to determine the physical characteristics of the individual DCPs transmitting through the system (DAMS, Digital Automated Monitoring Systems). NOAA maintains 1,085 DCPs on data buoys, river-gauging sites, and remote observing sites, out of a total of 8,024 DCPs using the GOES DCS. The NWS uses about 75 per cent of the 8,024 DCPs in river-stage and flood forecasting, collecting routine reports every one to six hours and special observations as needed. The GOES DCS is also the most reliable communicator of weather observations over ocean areas from data buoys, offshore platforms and tide gauges.

3.3.2 NOAAPORT

NOAAPORT satellite communication capabilities are identified with the AWIPS communications capabilities described in Section 3.4 and represent a consolidation of the two programs.

3.3.3 POES Communications

Communications capabilities of the current NOAA POES are used to collect environmental data from instrumented observing platforms worldwide and relay them to data collection centers such as NMC. The satellites also store polar imagery and soundings for relay to users and to data collection centers. Raw sounding data are received at Gilmore Creek, AK, and Wallops Island, VA, and sent to the NESDIS satellite data processing and distribution facility in Suitland, MD, then processed and relayed to NMC for use in NWP models. Other data relayed by POES include observations from drifting buoys, moored buoys, free-floating balloons, and remote automatic observing stations. The communications capabilities of the NOAA polar orbiting satellites just described are expected to be maintained by future polar orbiters through the mid 1990s.

3.4 Advanced Weather Interactive Processing System for the 1990s (AWIPS-90)

Automated observing systems of the future, such as satellites, NEXRAD, and wind profilers, will produce quantities of data far greater than can be supported by the current AFOS system. The NWS AWIPS-90 system is being designed to be a cost-effective replacement for the AFOS communications capabilities with its own increased processing and disseminating functions. The AWIPS-90 interactive capabilities, as well as the timetable for AWIPS-90 implementation, are described in section 4.6.

Interfaces for AWIPS-90 for receipt and exchange of data will be established for:

- the Satellite Broadcast Network (SBN), for satellite data and national guidance products; the broadcast will be narrow band at first, then wide band for GOES I-M;

- the Field Distribution Network (FDN), for exchange of local warnings and forecasts and of locally taken observations including NEXRAD, surface, and upper-air observations; and

- local communications, which will result in interfaces unique to specific locations for exchanging information with local authorities for emergency services.

The communication capabilities of AWIPS-90 will necessitate an examination by the NWS of data exchange with other agencies such as FAA, DOD, and COE. How and whether the methods of data exchange will change has not yet been determined.

A current understanding of the capabilities of the AWIPS-90 system at each NWS field office includes the acquisition of products from other offices, such as satellite imagery, satellite soundings, and numerical and manually produced guidance products. AWIPS-90 is also expected to support display of products among users at multiple sites. Still other capabilities of the AWIPS-90 system include the ability of one AWIPS site to interactively access another site and the provision of RJE from National Centers (NC) and RFCs to the NOAA Central Computer Facility. AWIPS-90 will be able to establish communications links to external systems, by direct link, by dial-out from AWIPS-90, and/or by initiation from an external system. External interfaces to and from AWIPS-90 will vary widely in definition, complexity and purposes, and include access to NEXRAD, ASOS, profilers and profiler hubs, ASDAR/ACARS, GOES DCS, spotter networks, marine observations NOAA Weather Wire Services, NOAA Weather Radio, emergency centers, and links to CWSUs collocated with FAA facilities. The variety of external interfaces will be further complicated by the requirements of individual AWIPS-90 sites and because many major NWS programs are not yet at a level of definition to allow the specification of the interfaces to these programs.

4.0 INTERACTIVE PROCESSING AND DISPLAY SYSTEMS

The acceleration of computer technology and the prospect of receiving prodigious quantities of observational data from future systems have made it necessary for NWS to determine efficient ways to process data and extract information quickly, both at field forecast offices and at NCs, for efficient use in preparing warnings, forecasts, guidance, and other services. The efficacious treatment of data must include useful graphic product displays, both of individual products and combinations of products. Observing systems such as satellites are near a state of development that threatens to overwhelm present NWS data processing and communications capabilities. Interim measures will be taken over the next several years to upgrade current capabilities until AWIPS-90 is fully operational.

4.1 Automation of Field Operations and Services (AFOS)

AFOS communications capabilities have been described in Section 3.2. AFOS also receives NMC graphic products -- analyses and NWP model outputs -- and distributes them to all NWS offices in the contiguous U.S. AFOS users can overlay up to three graphical products on one map background. AFOS by itself is not, however, capable of processing or even displaying high-resolution data such as from radar or satellites; enhancements such as SWIS (see below) are needed. AFOS has been the first step in the development of NWS operational interactive processing systems. Improved NWS interactive processing capabilities will culminate in AWIPS-90.

4.2 Satellite Weather Information System (SWIS)

SWIS, with its capability to combine satellite imagery and NMC-generated graphic material acquired from AFOS, has been under development since 1984. SWIS can acquire, store, display in color, and animate GOES visible, IR and water-vapor imagery, at full scale or on smaller sub-sectors. A microprocessor in the SWIS device converts NMC graphics to the satellite map projection and superposes the graphics upon the imagery. The master SWIS display device also provides the video output of both imagery and graphics to the AFOS Graphic Display Modules. SWIS provides the user with the capability to color-enhance the display data. Up to 16 enhancement curves can be stored in SWIS. Sixty-three SWIS units will be procured, with installation at all WSFOs, NCs, and Regional Headquarters. The SWIS program will operate until AWIPS-90 is in place.

4.3 Centralized Storm Information System (CSIS)

CSIS is based on the Man-Computer Interactive Data Processing System (MCIDAS) developed by the University of Wisconsin. NSSFC has used CSIS since 1982. CSIS interactively enables forecasters to assimilate large amounts of satellite and conventional data for a quick and thorough look at the state of the subsynoptic scale atmosphere, and to provide reliable analytical and interpretive information for developing subsynoptic scale forecasts and techniques.

Conventional surface and upper-air observations, radar, satellite imagery, satellite soundings, and profiler data may be combined; animated image sequences are available; and derivation of parameter fields is readily accomplished. All of these capabilities have been brought to bear on the economically important but incompletely understood processes at work in severe convective storms. CSIS, with its interactive capabilities, has since its installation enabled the NSSFC forecasters to be increasingly precise in the timing and positioning of tornado watch areas. At the present time it is not possible to transmit CSIS-derived analyses and products to field users; however, the users reap the benefits of improved NSSFC guidance products. CSIS continues to evolve in support of the specific needs of NSSFC. It is another intermediate system bridging the gap between NWS present and future operations and providing information on functional requirements and performance specification for AWIPS-90. It will be replaced in FY 89 by VDUC (Section 4.5).

4.4 Program for Regional Observing and Forecasting Services (PROFS)

ERL's PROFS program, initiated in 1980, has as its mission the improvement of short-range operational weather observing and forecasting services by the development, testing, and transfer to the operational arena of scientific and technological knowledge. PROFS has developed an interactive system that acquires, processes, and displays the data necessary to study the weather in a real-time operational setting. Prototype workstations access data from many sources, including Doppler radar, satellites, conventional surface and hydrologic stations, mesoscale surface networks, profilers, and lightning detectors, as well as NMC forecast products accessed by a collocated AFOS. The PROFS workstation is a functional experimental forerunner of interactive systems that will be built by the private sector for NWS operational deployment in the 1990s. Two workstations are operating at this time at the PROFS facility. A third was installed at WSFO Denver in October 1986 as part of DAR^{3}E (section 4.6.1) and is supported around the clock every day of the year. Until the end of summer 1987, data from PROFS were available to the CWSU at Longmont, CO. Valuable experience in real-time interactive data use has been gained by exercises conducted by PROFS involving field personnel and through regular use of workstations at CWSU Longmont and WSFO Denver. This experience has demonstrated that significant improvement can still be made in NWS forecasting, particularly on the subsynoptic scale. The information gained through PROFS experience has been incorporated into requirements documents for AWIPS-90.

4.5 VAS Data Utilization Centers (VDUC)

For several years, the NOAA Operational VAS Assessment (NOVA) Program has expended considerable effort in determining how best to use VAS sounding data operationally and interactively. VAS sounding data have been used interactively at NSSFC by means of CSIS, and in combination with satellite imagery at NMC and NHC through the use of remote terminals, to derive meteorological information from areas where conventional data is lacking; i.e., between conventional data stations over land, and over much of the ocean areas. Products derived from VAS sounding data that have shown potential utility include: multispectral and especially water-vapor imagery, mesoscale stability indices, storm motions for steering currents, and initial flow fields. Promising tests have also been conducted using VAS data in NMC forecast models. All these experiments have shown that VAS sounding data may be quite useful to NWS forecasters, particularly in combination with other information. The VDUC, developed with the help of NESDIS, will be the system by which VAS data will be processed at NCs and used operationally.

4.6 Advanced Weather Interactive Processing System of the 1990s (AWIPS-90)

The communications capabilities of AWIPS-90 have already been described in Section 3.4. Equally important to NWS operations will be the interactive processing capabilities of AWIPS-90. Both capabilities, unified in one system available to field personnel, will be a major part of NWS technological modernization efforts that reach their peak in the 1990s.

By the time AWIPS-90 is fully implemented, the warning and forecasting functions of today's WSFOs and WSOs will reside at Warning and Forecast Offices (WFO). AWIPS-90 will provide support for WFO operations, both for communications (Section 3.4) and for data processing. In the latter capacity, AWIPS-90 support will include the acquisition of advanced data sets (from NEXRAD, for example) as well as conventional data. AWIPS-90 will also be able to run simple forecast models tailored to the WFO's area of responsibility, using advanced observational data from satellites, NEXRAD, profilers, and ASOS; and it will automatically monitor the WFO warnings and forecasts as well as the weather in the WFO area of responsibility. In times of noncritical weather, when the WFO's warning and forecast mission would not be affected, AWIPS-90 capabilities will support forecast techniques development, products and services evaluation, and scientific training for the WFO staff. For all these functions, AWIPS-90 will be able to assimilate, process and display alphanumeric, image/graphic, and animated data. Hard (paper) copying devices, color capability of the terminal, large screen display, and operator alert will be some of the major workstation capabilities. An AWIPS-90 user will be able to: display alphanumeric and graphic products, including overlaid graphic products; process forecast guidance products and observational data; manipulate image/graphic data for local purposes (e.g., color-enhance satellite images); and program a sequence (procedure) of acquisition, display and manipulation commands. Unlike AFOS, which allows with some difficulty only limited expansion and modification, AWIPS-90 is expected to be modular in construction, allowing maximum flexibility and capability to support future analytical techniques, communications, information handling, and expansion.

AWIPS-90 capabilities will unify into one system the many data assimilation and display techniques and procedures used at today's typical NWS field site, plus those arising from the information from NEXRAD (Section 2.3.3), satellites (Section 2.2.4), profilers (Section 2.2.2), and surface observations (Section 2.1) in ways not yet fully devised. AWIPS-90 must do all these quickly, to assist the user in producing timely, accurate warnings and forecasts. And it is expected to operate reliably and efficiently so that the user's workload is not unduly increased by system problems. To understand user needs better, NWS will do extensive prototyping that will involve existing interactive systems in specific operational environments. The first prototype workstations for functional integration into existing AFOS complexes will be developed around FY 89 at a limited number of NWS field sites.

Two areas in which AWIPS-90 prototyping programs have been defined are the operations of the WFO and hydrologic forecast services. Accordingly, the following two sections of this report are devoted to these AWIPS-90 prototype programs.

4.6.1 Denver AWIPS-90 Risk Reduction and Requirements Evaluation (DAR^3E)

This exercise, developed in conjunction with PROFS, began in 1986 and is focused on the field forecast office environment (specifically at WSFO Denver). The current version of the exercise is DAR^3E-II. It has these objectives: to determine experimentally the optimum AWIPS-90 workstation console functional and physical design characteristics; and to establish relationships among forecast capabilities and local data base content, data/product form and format, and applications inventories. It is the first field test at a NWS facility of products and techniques that have evolved from several years of real-time experimentation by PROFS that used workstations and software in a quasi-operational setting. One experimental workstation replaces one AFOS console at Denver WSFO during this exercise, providing AFOS capabilities along with the experimental ones; public and possibly aviation forecast products and services are produced on the workstation. In particular, the exercise will operationally evaluate the workstation and the capabilities for: use and interpretation of data types not found in field offices today -- Doppler radar and profilers, for example; the production and use of combined data sets; improved data assimilation and processing, including analysis/forecast techniques and mesoscale models; and interactive data processing, interpretation and display. The workstation will access the PROFS Experimental Data Facility (EDF) for the necessary data instead of directly linking to the various PROFS-operated sensor networks.

4.6.2 Prototype Real-Time Operational Test, Evaluation, and User Simulation (PROTEUS)

PROTEUS is a cooperative demonstration project operated under the auspices of the NWS Office of Hydrology (OH). As part of the risk reduction strategy of the AWIPS-90 program development plan, PROTEUS will demonstrate enhanced computer systems hardware and software which will be required by RFCs in the AWIPS-90 era. In connection with DAR^3E-II, PROTEUS will also demonstrate the interaction between RFCs and WFOs. Near-term hardware and software enhancements are being provided to the following offices: NWS Office of Hydrology (OH), Missouri Basin RFC (MBRFC), Columbia Basin RFC (CBRFC), Mid Atlantic RFC (MARFC), Alaska RFC (AKRFC), and Tulsa RFC (TURFC). The PROTEUS Project began limited operations in 1986. It will be active during the requirements, definition, and development phases of AWIPS-90.

The design and development of the PROTEUS system is based on the projection of the NWS operational environment envisioned for the 1990s as described in the AWIPS-90 Operations Concept. The knowledge gained from the PROTEUS demonstration will be used by the AWIPS-90 Program Office in refining and applying AWIPS-90 requirements and specifications. PROTEUS will demonstrate the following high-risk AWIPS features in an effort to reduce the risk associated with their design and implementation:

- Automatic data handling and quality control
- Interactive NWS River Forecast System (NWSRFS)
- RFC/WFO interaction -- data and products traffic
- Effective use of the NOAA Central Computer Facility (NCCF)
- Integration of Data Base Management Systems (DBMS) with forecast operations
- Backup
- Data exchange with water resources agencies
- Enhanced calibration
- Data archiving and retrieval

Further, PROTEUS will provide some insights into the service adjustments that NWS must consider as a result of the introduction of this new technology into operational field offices. In this vein, the following areas will be investigated:

- o Coordination of hydrologic services between WFO and RFC
- o System support requirements
- o Human factors

Five field sites have been selected as PROTEUS test facilities. MBRFC will be the primary demonstration center for data management and quality-control techniques. MBRFC will also demonstrate the interaction and the data and products traffic between AWIPS-era offices. MARFC will focus on interactive forecasting, interactive graphics, and integration of event reporting sensor data collected by IFLOWS and ALERT systems. CBRFC will concentrate on interactive calibration techniques, interactive graphics, historical data handling, and long-range water resource forecasting procedures. TURFC will be the primary demonstration site for real-time data exchange between RFCs and cooperating water resources agencies, and for the integration of NEXRAD data into hydrometeorological operations. The OH Hydrologic Research Laboratory (HRL) and the Hydrologic Operations Division (HOD) will develop, for the PRIME computer, versions of the batch and interactive NWSRFS, interactive graphics, and enhanced calibration, as well as support modeling and data-handling requirements of the PROTEUS development effort. The Alaska Region will investigate the use of general purpose workstations to upgrade the computing capability of a super minicomputer. The Alaska Region will also demonstrate use of interactive graphics on general purpose workstations. OH will provide national-level hardware, software, and network configuration management, as well as database administration. The PROTEUS Project Field Office in Kansas City, MO, provides hardware and network configuration management; two positions in HOD will provide the software configuration management and database administration functions. Refer to Appendix E of the PROTEUS Project Plan for a detailed plan of activities.

4.7 Concepts in Interactive Processing using Artificial Intelligence (AI)

In its efforts to automate its field operations, NWS is seeking to make the forecaster's decision-making processes easier. In particular, NWS is considering applications of AI such as knowledge-based expert systems in its warning and forecast operations.

Current computerized guidance does not allow the user to determine the steps involved in arriving at a guidance product; the user must choose the most appropriate product for the particular forecast based on experience with the product. AI is considered a potentially useful way to inject "reasoning" by the computer into the forecast process by means of decision-making processes (heuristics). A major application of AI could be to systematize weather of forecasting techniques -- "rules of thumb" used by individual forecasters or applicable to certain situations, climatological input, and evaluations of guidance products.

AI as applied to the NWS mission has been redefined as interpretive processing; that is, the use of computerized interactive procedures to assist the forecaster in the decision-making process. Interpretive processing is a stream of functions to organize the decision making: validate the raw input;

identify the significance with respect to developing updated or entirely new products; determine possible consequences of various alternative actions; establish actual product sequences; and validate product elements. Interpretive processing would benefit NWS in three ways. First, it would provide improved data analysis and decision-making support due to enhanced consistency and thoroughness; this is potentially critical because of the tremendous increase in data and products expected from observing systems like ASOS, NEXRAD, and profilers. Second, by systematizing the forecasting heuristics, interpretive processing would support training of new forecasters; in the light of the greater need for forecasters in the restructured NWS of the 1990s, this benefit looms large. Finally, interpretive processing would maintain the skills of experienced forecasters; this benefit would be most apparent when forecasters face infrequent, significant or unfamiliar weather situations. By the use of interpretive processing as an extension of AI, the best forecast knowledge would become available to the forecasters.

Interactive processing systems that are current or being developed, like CSIS, SWIS, and AWIPS-90, also have interpretive processing capability. Examples of forecast techniques that fit the heuristics concept of AI include severe-weather stability indices and terminal visibility as a function of wind direction. Examples of products that could lend themselves to AI application are the NSSFC convective outlook and the diagnostic techniques used at NHC to evaluate hurricane prediction models.

5.0 DISSEMINATION OF NWS WARNINGS, FORECASTS, AND OTHER PRODUCTS TO EXTERNAL USERS

The last 15 to 20 years have brought about a radical change in NWS methods of getting its products to its users. Around 1970, the primary methods of disseminating NWS products were by teletype circuits and, especially in critical weather events, by telephone. But teletype circuits were slow at best; their traffic flow was often chaotic in bad weather. Manual methods of message composition such as typing and cutting tapes were labor-intensive and error-prone. Telephones to the weather offices were overburdened at the very times information was most needed. NWS has developed a number of dissemination methods over the years which have led to more efficient dissemination of products and retention of the generally high esteem long held by the public towards NWS. Even better dissemination techniques are being planned as NWS seeks to make maximum use of technological improvements in satisfying what is certain to be an escalating demand for its products and services. The following sections describe current and future NWS methods of product dissemination.

5.1 Current Dissemination Operations

5.1.1 NOAA Weather Wire Services (NWWS)

The NWWS is a series of 51 data circuits -- mainly teletype, but also FM sub-carrier and microwave -- organized generally within individual states. NWS enters its products at a WSFO or backup WSO on the individual circuit via AFOS; the circuit schedule is programmed to provide a hard copy of weather information to NWWS subscribers in the continental U.S. The majority of the more than 2,700 subscribers are commercial broadcast radio and TV stations, cable TV stations, and state government agencies. NWWS is being upgraded to 1200 bps nationwide through a competitive solicitation. Contract award is expected in CY 88.

5.1.2 NOAA Weather Radio (NWR)

NWR provides continuous 24-hour weather broadcasts from selected NWS offices on seven VHF-FM frequencies, from 380 transmitter sites in or near population centers across the nation. NWS warnings and forecasts are recorded on tape cassettes and are broadcast in sequence; warnings and other important weather information can be broadcast live when issued, with tone-alert signals to activate specially equipped receivers. In addition to the primary transmitting sites, NWS by agreement with state and private organizations has been able to disseminate NWR information further to parks and highway rest stops, telephone voice-paging systems, and commercial media for rebroadcast.

NWS is exploring, along with local and state government agencies, the use of low-powered AM radio transmitters to broadcast not only the weather information heard on NWR but additional items such as road conditions. Another potential means of providing weather information to travelers is the addition of a NWR receiver as a safety feature for motor vehicles. Efforts are under way to work with auto manufacturers to offer NWR receivers with new cars.

5.1.3 NOAA Weather-by-telephone (WBT)

NWS uses some 530 recorded telphone systems at field sites nationwide to provide users with current forecasts. Ring-through devices which allow direct contact by users with NWS personnel are used at 179 sites. NWS in most areas still disseminates warnings directly by phone to selected users. In cooperation with telephone companies in many metropolitan areas, NWS provides forecasts and current weather to the companies, which record the information and offer the service to users for the cost of a local call. All of these methods of dissemination have been in use for many years, but they have become labor-intensive and costly.

To provide cost-effective services that satisfy the dissemination needs of both NWS and the public, NWS has entered into a memorandum of understanding (MOU) with private-sector cooperators for the provision of weather-by-telephone (WBT) at no cost to the Government. This encourages private-sector activity in this area. Under the terms of the MOU, NWS discontinues its regular WBT services from its local offices, but maintains an administrative line for public access. The cooperator provides a sponsored recording of the latest weather at no extra cost to the caller and provides at least an equivalent number of lines as was previously required by NWS for the public. The cooperator is also required, at its own expense, to access the data required from the local NWWS and broadcast the official NWS forecasts with attribution.

The current practice is to enter into a MOU with any entrepreneur who will provide a locally sponsored WBT service under the terms of the MOU. The MOU, however, does not give the cooperator exclusive rights to the WBT service in the area. NWS must deal with as many private WBT services as the marketplace will bear.

In June 1985, NWS concluded an agreement with AT&T Communications and NBC News to provide recorded information from NHC to AT&T on named tropical cyclones in the North Atlantic Ocean. The recorded information is made available on a "900" number at a cost of 50 cents per call and is updated whenever new advisories are issued by NHC. During the 1985 hurricane season, more than 665,000 calls were received, some 587,000 during Hurricane Gloria alone.

5.1.4 Facsimile Distribution Systems

Two national facsimile distribution systems are currently in operation: the Digital Facsimile Network (DIFAX) and the National Facsimile Network (NAFAX). The DIFAX service is a high speed digital system (720 spm) which can provide about 300 charts per day. The DIFAX charts include products related to the international aviation, agriculture, and the NAFAX transmission, excluding satellite photos. The NAFAX service is a slow speed analog system (120 spm) which can provide about 100 charts per day. The NAFAX charts include analyses, prognoses, selected observed data, and some satellite photos. Both of these facsimile networks serve users at NWS, FAA, DOD, and nongovernment organizations.

NWS has contracted with a private communications company (Equatorial Communication Company) to convert the two NWS terrestrial facsimile networks to satellite broadcast dissemination.

5.1.5 NOAA Family of Services (FOS)

Since 1983, NWS has provided for external-user access to near real-time weather and flood information through a family of medium-speed communications services which are accessed in the Washington, DC area. Called the Family of Services (FOS), it provides the following eight services:

- Public Product Service (PPS, 1,200 bps), carrying: all public warnings and watches, and various hydrologic, agricultural, and miscellaneous forecasts and products;
- Public Product Service Backup (PPS-2), provided as a backup service to the PPS for those subscribers requiring it;
- Domestic Data Service (DDS, 1,800 bps), carrying: basic observations, and various aviation, marine, and miscellaneous products;
- International Data Service (IDS, 1,800 bps), carrying: worldwide surface and upper-air observations and other miscellaneous products;
- Numerical Products Service (NPS, 4,800 bps), carrying: analyses and forecasts derived from NMC's Nested Grid Model and the global spectral model out to 7 days. Forecasts prepared by the European Centre for Medium Range Forecasts are also carried;
- National Facsimile Service (NAFAX), carrying analyses, prognoses, observed data, and satellite photographs in graphical form; and
- Digital Facsimile Service (DIFAX), carrying analyses, prognoses, and other information similar to that on NAFAX.

All the above services may be obtained from NWS for set user fees which are reviewed and updated annually. Private-sector companies resell data as received and/or provide value-added services for specialized users based on information derived from the FOS.

5.1.6 TV, Radio, and Newspapers

TV and radio stations rely on NWWS, FOS, and NWR for routine weather information; they will often communicate directly with NWS offices, including visits and live, on-air interviews, to disseminate information about significant weather events. NWS has two specialized dissemination uses of TV. The first, a program called "A.M. Weather," uses NWS warnings and forecasts emphasizing aviation weather compiled and broadcast by NWS and NESDIS personnel, and tailored to various parts of the nation. This program is funded by NWS, FAA, and private aviation-oriented companies and is broadcast on the 271 stations of the Public Broadcast Service (PBS) network in the early morning. The second is a system set up by agreements between NWS and cable TV companies whereby NWS includes coded information within its products to allow automatic routing, reformatting, and rebroadcast by the cable companies. Among the primary cable-TV disseminators is the Weather Channel, which is staffed by private-sector personnel but broadcasts NWS warnings, forecasts, and observations along with brief segments of reformatted alphanumeric NWS product displays tailored to specific communities by local cable companies.

Twenty-five years ago, direct commercial radio broadcasts from NWS field offices were common. They were encouraged as a basic method of disseminating NWS (then the U.S. Weather Bureau) products to the American public. NWS has since progressed with its ability to provide broadcast weather services. NWR has been deployed across the country and now reaches over 90 percent of the population. With growth and development of the private meteorological sector, NWS has encouraged private meteorologists to enhance the provision of vital weather information to all sectors of the country. Consequently, even though routine commercial radio broadcasts have served a useful purpose, they are being phased out. NWS will continue its policy of permitting its offices to provide direct commercial radio weather broadcasts on a non-routine basis during periods of hazardous weather conditions. It will also continue its policy of permitting the rebroadcast of NWR programming on commercial radio and television stations.

Newspapers, once the primary means for disseminating weather information, have now assumed a dissemination role subordinate to that of television and radio. The weather page of USA Today, however, has sparked a renaissance in newspaper weather reporting, with many newspapers including an improved forecast map and more expanded data and forecast coverage in their daily weather sections.

NWS has long enjoyed a generally cordial relationship with the print media and cooperates with it in every way possible, especially when called upon to furnish interviews and background information in connection with news reports of weather disasters or unusual events. With the growth of the private weather information service sector, the NWS role of direct provision of routine services to newspapers has diminished, such support being considered basically the province of the private sector. Although 10 NWS field offices currently provide weather maps to local newspapers or press services on a regular basis, the goal is to phase out such service over the next few years.

5.1.7 Marine Radio Facsimile Systems

Radiofacsimile broadcasts of marine weather information were first provided operationally by the U.S. Navy during World War II. Although several Navy broadcast services continue at this time, the NWS marine radiofax program centers on coastal WSFOs providing local or regional coverage. Individual broadcast services now in operation cover the Gulf of Alaska, the Gulf of Mexico, the Great Lakes, the coastal waters of New England and the mid-Atlantic regions, and the Hawaiian islands and the Federated States of Micronesia. The NWS radiofax program uses the radio transmission facilities of the U.S. Coast Guard, commercial marine radio stations, and academic institutions.

5.1.8 Telephone Circuits

Virtually all of the current NWS dissemination methods discussed already have been predicated on the assumption that data, products and services will be sent via telephone circuits which may be composed in whole or in part of land lines, radio transmissions, and satellite links. Computer-to-computer communication will for the foreseeable future make use of telephone circuitry. While satellite transmission technology will be increasingly used for NWS dissemination, the humble telephone will still play a very important role in how the NWS communicates -- from the virtually instantaneous transfer of huge quantities of data between computers to the inquiry of a citizen about the hurricane near Bermuda. Recorded information available by phone -- forecasts and other services -- will continue to be important in the dissemination of NWS weather products. The days might be gone when people called their local weather offices for all kinds of weather information, primarily because of the many ways NWS now uses to dispense its messages; but there will always be legitimate user requests that can be dealt with in no other way than by a phone call.

5.2 Planned and Future Dissemination Systems

5.2.1 Voice Synthesis Technology

NWS has been investigating methods of using to its advantage the rapidly developing field of voice synthesis technology to develop a computerized means of automating messages for NWR. There are two classes of systems available in voice synthesis technology: text-to-voice (synthetic) speech, and phrase concatenation speech. Synthetic speech translates text messages into combinations of predefined digital electronic sounds that result in understandable, speech-like messages. Although synthetic speech is perhaps the most useful and versatile form of the present voice synthesis technology, its use in NWR message formatting will be limited due to relatively low voice quality. Synthetic speech has been used by FAA in demonstrations to produce messages for pilot weather briefing.

The second type of voice synthesis technology, phrase concatenation speech, uses prerecorded words or phrases in digital form to produce the speech. It uses a predefined vocabulary and thus limits the types of spoken message that can be used. Phrase concatenation speech is of higher quality than synthetic speech; it is more human-sounding and less likely to offend the hearer with an artificial, obviously synthetic tone.

5.2.2 The NOAA Weather Radio Voice Synthesis Project

This project aims to provide a demonstration of voice synthesis technology to produce automated messages for broadcast over NWR. In October 1985, NWS Western Region began to broadcast the Salt Lake City hourly observation on NWR in the form of a concatenated message. Developments being tested include the automation of larger products like forecasts, with manual voice override for severe-weather information requiring immediate broadcast and for products that cannot be encoded. In this project, the vocabulary is first defined; then the software is written to decode the raw information, assemble the voice product and maintain the product broadcast on NWR. The project demonstration system uses data received from AFOS into an IBM PC/XT, which decodes the data, encodes a voice product, and interfaces to a NWR console. The project thus far shows considerable promise.

The Coast Guard at Portsmouth, VA, is currently broadcasting NWS marine products using synthesized voicing technology. NWR broadcasts using synthesized voice have been used in Alaska as well.

Also being tested in this project is tone-cuing of products. The test is being conducted in NWS Central Region at Kansas City, MO, using a local radio and cable TV station. Inaudible tones added at the beginning and end of products will allow automatic selection and recording of NWS products by the news media.

6.0 FIELD RESEARCH EXPERIMENTS EMPLOYING NEW TECHNOLOGIES

NWS will participate in a number of field experiments and demonstrations over the next several years to focus on gaining knowledge of meteorological processes in the subsynoptic scale and to evalute the use of the new technologies in operational settings. Subsynoptic meteorological processes have obvious importance to the economic well-being of the nation as well as a role, still incompletely understood, in the larger-scale processes of the atmosphere. Field experiments are designed to help NWS understand small-scale processes, to learn how to use the information provided by the experiments to improve warnings and forecasts, and to determine the effectiveness of the various technologies involved in the projects. Specific examples of such projects are described below.

6.1 Genesis of Atlantic Lows Experiment (GALE)

This experiment was designed to investigate the atmospheric processes at work during cyclogenesis over the southeastern U.S. The area under investigation was selected because weather caused by cyclones originating there frequently affects the economy of the country's most populous region, the mid-Atlantic and northeastern states, and because cyclogenesis processes in that region are inadequately understood by the meteorological community. GALE will intensely investigate the mesoscale and sea-air interaction processes associated with cyclone development. GALE was considered a preparatory phase for one segment of the National STORM Project (Section 6.2).

The GALE field experiment, running from January 15 through March 15, 1986, concentrated on the coastal region from Virginia through Georgia and adjacent offshore areas. It mustered the following armada of sensors for its observational tasks:

- 41 existing NWS sites, and 12 additional ones, taking 3-hourly raobs during intensive measuring periods
- 5 coastal WSR-57 radars providing digitized data
- GOES VAS sounding data and rapid-scan imagery
- Dropsondes at 150-km spacing and 6-hour intervals over water
- 2 instrumented research vessels in the Carolina coastal waters
- 50 automated mesonet stations spaced 60 km apart, from South Carolina through Virginia
- 8 buoys added off the southeastern U.S. Coast
- 5 Doppler radars
- 6 instrumented towers
- 8 research aircraft

All of these instruments augmented the current conventional surface observation network. Besides the additional data available in real time to NWS operations, GALE will provide a comprehensive series of data sets for use by researchers over the next few years.

6.2 The National Stormscale Operational and Research Meteorology (STORM) Program

In this program, many organizations will be involved in a nationwide effort to understand better the development and forecasting of stormscale (i.e., mesoscale) weather producers that have profound effects on the nation's people and economic activity. The program has two goals: to enable meteorologists (public and private) to observe and predict the occurrence of small-scale weather phenomena with substantially improved timeliness and accuracy, and to apply improved predictive capability and understanding to the tasks of protecting the public, serving the national economy, and meeting defense requirements. NOAA participants in planning for the STORM Project are NWS, NESDIS, and ERL. Other Federal Government participants are: DOD, Department of the Interior (DOI), DOT, Environmental Protection Agency (EPA), NASA, and National Science Foundation (NSF). These agencies will contribute to both the operational and the research segments of the project; extensive assistance for both components is also expected from private universities under the aegis of the National Center for Atmospheric Research (NCAR).

The STORM Project is proposed to be a two-stream effort, involving operational and research segments to strive for better understanding of small-scale weather processes. The operational segment of STORM is designed to exploit existing knowledge and available technology in the service of society; the research segment is designed to provide understanding of weather phenomena, to apply this understanding to improve forecast operations, and to help improve the operational observational system.

The current plans for STORM emphasize taking advantage of the new observing systems tied to the NWS modernization effort -- especially NEXRAD, GOES I-M, ASOS, and the wind profiler. STORM will focus on: developing and testing new forecast techniques for stormscale weather; implementing four-dimensional data assimilation into numerical models for operations and research; and organizing special field experiments to address crucial gaps in understanding storm-scale weather systems.

A major field program will be initiated under STORM beginning about 1990 in the Central U.S. STORM-Central will be a five-year project punctuated by several special observing periods (SOP). The key SOP is scheduled for 1992 and will be aimed specifically at studying the interaction of meteorological scales of motion which control mesoscale convective systems (MCS), which are beneficial rain-producers as well as notorious originators of severe weather in the U.S. during the warm part of the year. During other periods, STORM-Central will address the difficult-to-forecast small scale features of winter storms over the Plains and Midwest.

6.2.1 Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central (PRE-STORM)

STORM-Central will use new observing systems and new sensing strategies, most of which are untried in an operational field setting. To prepare for the intensive field phase of the program, NOAA established the Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central (PRE-STORM) as a cooperative effort among the Weather Research Program (WRP) of ERL, NSSL, NCAR, NWS, and university groups to do field testing and evaluation of sensor systems, and to collect data on MCSs for research. The PRE-STORM project was conducted in May and June 1985. Its goals were to investigate the development, evolution and structure of MCSs and to evaluate new sensing systems and develop observational strategies. The array of instruments used in PRE-STORM included:

- o NWS WSR-57s equipped with RADAP II and two Doppler pairs
- o 10 rawinsondes, including 8 special sites
- o 3-hourly releases from 13 NWS rawinsonde sites
- o Three wind profiler systems
- o Automated surface observation mesonet of about 90 sites
- o Two lightning location networks

In addition, NOAA provided two P-3 aircraft, one equipped with a 3-cm Doppler vertically scanning radar. Several other aircraft were used to study boundary-layer measurements and cloud structure. PRE-STORM was based operationally at WSFO Oklahoma City.

6.3 Wind Profiler Demonstration Project (WPDP)

Experimental wind profilers (Section 2.2.3) have been operated by ERL in Colorado since 1980. They have provided considerable information, both from the systems-engineering and from the meteorological viewpoints, on the utility of the application of Doppler radar technology to the remote sensing of upper-air winds. Although ERL's profilers are primarily for research, their data have been used by WSFO Denver and CWSU Longmont to assist in warning and forecast preparation. NWS, in conjunction with ERL, plans to use networked wind profiler data in its efforts to know about regional-scale weather systems.

Preliminary steps to the establishment of a nationwide wind profiler network consist of the operation of a mini-network of three wind profilers in Colorado beginning in 1986, followed by the Wind Profiler Demonstration Project (WPDP), which calls for the establishment of a demonstration network having some of the expected characteristics of a national network. The Colorado mini-network serves two purposes: to begin developing operational uses for network data, and to initiate the development of an efficient communications system for disseminating wind profiler data and products. Techniques already devised to calculate vorticity, divergence and vertical velocities at the centroid of a triangle will be used to investigate subsynoptic-scale systems. A central Hub has been developed, which serves as a prototype of a data collection, processing, and distribution center for a network of wind profilers. The WPDP, a joint NWS/ERL effort, calls for the establishment of the Wind Profiler Demonstration Network (WPDN) of 31 wind profilers in the midwestern U.S. around 1990, with the active phase of the project running from 1990 through 1992. The configuration of the WPDN will cover a major part of the U.S. between the Appalachians and the Rockies. This project will formally decide the issue of the utility of a national profiler network, but there seems little doubt about the potential usefulness of the unique and intensive perspective such a net would provide for observing and forecasting small-scale weather systems.

Although wind profilers are the most important elements of the Colorado mini-network and later the WPDN, they may not be the only instruments sampling the atmosphere in those networks. The Colorado mini-network includes a thermodynamic profiler at Stapleton Airport. The WPDN may be enhanced by thermodynamic profilers and surface sensors.

6.4 Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA)

This project, organized by the Office of Naval Research, is aimed at improvment of the understanding and forecasting of intense storms that develop off the coasts of the U.S. and Canada in winter. Special focus is on cyclones whose central pressure falls by at least 10 millibars in 6 hours and at least 24 millibars in 24 hours. Such storms often produce winds exceeding 75 mph and heavy precipitation; they occur five or six times during a typical winter.

The main phase of ERICA will take place from December 1988 through February 1989 off the northeast coast of the U.S., as far north as Newfoundland. The project will deploy several research aircraft (including two NOAA P-3Ds) with in-situ measurement, radar, and dropsonde capability. Dense coverage of ocean surface measurement will be achieved with drifting buoys that can be dropped from aircraft. Satellite data and ships of opportunity will be used to augment oceanic data. Two Doppler radars will be available on the coast to monitor offshore winds and precipitation, and conventional data from land areas will be enhanced for the experiment. Atmospheric Environment Service of Canada will participate and will provide additional observing platforms and data augmentation.

NOAA and NWS will give considerable support to ERICA. In particular, NMC will provide nowcasts and forecasts for the ERICA Operations Center in the World Weather Building at Camp Springs, MD, and will collaborate in data archiving. NWS Eastern Region will provide special forecast support and cooperate in augmenting upper-air soundings during ERICA's intensive observing periods. NDBC will provide quality control for data transmitted from ERICA drifting buoys. The data set gathered during the experiment should offer many opportunities to test new forecast techniques and numerical prediction models in the future.

7.0 SUMMARY

This report has been an attempt to freeze in time a picture of the rapidly changing evolution of NWS programs for observing and forecasting the weather and for disseminating information. It is a larger report than its predecessors of 1981 and 1986 because of technological advances, new programs, and the sharpening of focus of current programs. It is quite possible in this report that a program may have received insufficient attention or may have been left out. To rectify any omissions, and to keep abreast of further rapid advances in the NWS use of technology in its mission, the Office of Meteorology will attempt to update this report on perhaps a biennial basis. Copies of this report may be obtained from the NWS Office of Meteorology.

8.0 ACKNOWLEDGEMENTS

This report was assembled by Brian G. Smith of the Office of Meteorology. It has been a cooperative effort among many segments of NWS, whose efforts on behalf of OM in updating the previous version of the report are gratefully acknowledged. In particular, we thank the following people for their reviews, comments, and suggestions:

- Office of Hydrology
  Dick Farnsworth, Hydrological Research Laboratory
  Dale Lillie, Project Manager, PROTEUS

- Office of Systems Development
  Hank Schmidt, Program Development Staff

- Office of Systems Operations
  Joe Facundo, Sounding Systems Branch
  Paul Hexter, Observing Systems Branch
  Gerry O'Brien, Chief, Surface Observations Section
  Jon Parein, Basic Observations Branch
  Dick Haas, Chief, Domestic Telecommunications Section

- Office of Legislative Affairs
  Ed Gross, Constituent Affairs Officer (NWS)
  Walt Cottrell, Constituent Affairs and Industrial Meteorology for the NWS

- Office of Meteorology
  Ira Brenner, Services Development Branch
  Rick Decker, Systems Requirements Branch
  Marty Deiseroth, Systems Requirements Branch
  Danny Foster, Chief, Overseas Operations Division
  Mary Heffernan, Systems Requirements Branch
  Ron Lavoie, Chief, Program Requirements and Planning Division
  Bob McLeod, Services Development Branch
  Henry Newhouse, Systems Requirements Branch
  Gary Petti, Marine and Applied Services Branch
  Randy Racer, Chief, Services Development Branch
  Tom Reppert, Marine and Applied Services Branch
  Mike Young, Marine and Applied Services Branch
  Fred Zbar, Chief, Systems Requirements Branch

APPENDIX A

Glossary of Acronyms and Abbreviations Used in this Report

ACARS	ARINC Communications and Reporting System
AFCU	Area Forecast Coordination Unit
AFOS	Automation of Field Operations and Services
AHOS	Automatic Hydrologic Observation Systems
AI	Artificial Intelligence
AKRFC	Alaska RFC
ALDS	Automatic Lightning Detection System
ALERT	Automated Local Evaluation in Real Time
AMOS	Automatic Meteorological Observing Station
AMTS	Advanced Meteorological Temperature Sounder
AMSU	Advanced Microwave Sounding Unit
ARINC	Aeronautical Radio, Incorporated
ART	Automatic Radio Theodolite
ASAP	Automated Shipboard Aerological Program
ASDAR	Aircraft to Satellite Data Relay
ASOP	Automation of Surface Observations Program
ASOS	Automated Surface Observation System
ATDDCS	Automated Tone Dial Data Collection System
ATS	Applications Technology Satellite
AVHRR	Advanced Very High Resolution Radiometer
AWIPS-90	Advanced Weather Interactive Processing System for the 1990s
AWOS	Automated Weather Observing System
BLM	Bureau of Land Management
bps	Bits per second
CATS	Conical Atmospheric Tropopause Sounder
CBRFC	Columbia Basin RFC
CDDF	Central Data Distribution Facility
C-MAN	Coastal Marine Automation Network
COE	Corps of Engineers
CRT	Cathode Ray Tube
CSIS	Centralized Storm Information Service
CWSU	Center Weather Service Unit
CY	Calendar year
DAMS	Digital Automated Monitoring Systems
DAR^3E	Denver AWIPS-90 Risk Reduction and Requirements Evaluation
DBMS	Data base management system
DCP	Data Collection Platform
DCS	Data Collection System
DDS	Domestic Data Service
DIFAX	Digital Facsimile Network
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DOD	Department of Defense
DOI	Department of the Interior

DOMB	Deep Ocean Moored Buoy
DOT	Department of Transportation
D/RADEX	Digitized Radar Experiment
DS	Dwell Sounding
D/VIP	Digital Video Integrator and Processor
EDF	PROFS Experimental Data Facility
EFAS	Enroute Flight Advisory Service
EOS	NASA Earth Orbiting System polar platform
EPA	Environmental Protection Agency
ERICA	Experiment on Rapidly Intensifying Cyclones over the Atlantic
ERL	Environmental Research Laboratories
ERS-1	European polar orbiting salettite of the 1990s
FAA	Federal Aviation Administration
FDN	Field Distribution Network
FEMA	Federal Emergency Management Agency
FFAS	Flash Flood Alarm System
FGGE	First GARP Global Experiment
FOS	Family of Services
FSS	Flight Services Station
FY	Fiscal year (October through September for U.S. Government)
GALE	Genesis of Atlantic Lows Experiment
GARP	Global Atmospheric Research Project
GMS	Geostationary Meteorological Satellite (Japan)
GOES	Geostationary Operational Environmental Satellite
GOES I-M	Next-generation GOES
GOWON	Gulf Offshore Weather Observing Network
HIRS	High-resolution Infrared Sounder
HIS	High-resolution Interferometer Sounder
HOD	OH Hydrologic Operations Division
HRL	OH Hydrologic Research Laboratory
IBM	International Business Machines
ICRAD	Interactive Color Radar Display
IDE	Isolation Distribution Equipment
IDS	International Data Service
IFLOWS	Integrated Flood Observing and Warning System
INMARSAT	International Marine Satellite program
IR	Infrared
JAWOP	Joint Automated Weather Observing Program
JERS-1	Japanese polar orbiting satellite of the 1990s
KaPP	Kansas Pilot Project
LFM	Limited Fine Mesh
LFWS	Local Flood Warning System
LNB	Large Navigational Buoy
LORAN-C	Long Range C-band
LWO	Local Weather Office

MARD	NWS Modernization and Restructuring Demonstration
MAREP	Marine Report
MARFC	Mid Atlantic RFC
MBRFC	Missouri Basin RFC
MCIDAS	Man/Computer Interactive Data Acquisition System
MCS	Mesoscale Convective System
METEOSAT	European Space Agency geostationary meteorological satellite
MOU	Memorandum of understanding
MSI	Multi-spectral imaging
MSU	Microwave Sounding Unit
NAFAX	National Facsimile Network
NASA	National Aeronautics and Space Administration
NC	National Center
NCAR	National Committee on Atmospheric Research
NCCF	NOAA Central Computer Facility
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next-Generation Radar
NHC	National Hurricane Center
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAA-K,L,M	Next-generation NOAA polar-orbiting satellites
NOAAPORT	NESDIS program to upgrade satellite communications
NOS	National Ocean Service
NOVA	NOAA Operational VAS Assessment
NPS	Numerical Products Service
N-ROSS	U.S. Navy's Remote Ocean Sensing System
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NWP	Numerical Weather Prediction
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSH	NWS Headquarters
NWSRFS	NWS River Forecast Service
NWWS	NOAA Weather Wire Service
OH	NWS Office of Hydrology
OM	NWS Office of Meteorology
OWSE-NA	Operational World Weather Watch System Evaluation of the North Atlantic
PBS	Public Broadcast Service
PC	Personal computer
POES	Polar-Orbiting Environmental Satellite
PPI	Plan-position indicator
PPS	Public Product Service of FOS
PPS-2	PPS backup of FOS
PRE-STORM	Preliminary Regional Experiment for STORM-Central
PROFS	Program for Regional Observing and Forecasting Services
PROTEUS	Prototype Real-time Observational Test, Evaluation and User Simulation

RADAP	Radar Data Processor
RADID	Radar Information Display
RAMOS	Remote AMOS
READ	Remote Entry Alphanumeric Device
RFC	River Forecast Center
RJE	Remote Job Entry
ROSA	Remote Observation System Automation
RRWDS	Radar Remote Weather Display System
SAR	Synthetic Aperture Radars
SBN	Satellite Broadcast Network
SEAS	Shipboard Environmental Acquisition System
SEASAT	Sea Satellite
SFSS	Satellite Field Services Station
SHEF	Standard Hydrologic Exchange Format
SITOR	Simplex Teletype Over Radio
SMCC	Systems Monitoring and Coordination Center
SOP	STORM Project special observing period
SST	Sea Surface Temperature
SSU	Stratospheric Sounding Unit
STORM	Stormscale Operational and Research Meteorology
SUNYA	State University of New York at Albany
SWIS	Satellite Weather Information System
TIROS	Television and Infrared Observation Satellite
TOGA	Tropical Ocean Global Atmospheric Experiment
TOVS	TIROS Operational Vertical Sounder
TURFC	Tulsa RFC
UHF	Ultra High Frequency
USGS	United States Geological Survey
VAS	VISSR Atmospheric Sounder; Vertical Atmospheric Sounder on GOES I-M
VDUC	VAS Data Utilization Center
VHF	Very High Frequency
VIL	Vertically Integrated Liquid
VISSR	Visible and IR Spin Scan Radiometer
VOS	Voluntary Observing Ship
WBT	Weather-by-telephone
WFO	Warning and Forecast Office
WINDSAT	Wind Satellite
WMO	World Meteorological Organization
WPDN	Wind Profiler Demonstration Network
WPDP	Wind Profiler Demonstration Project
WR	NWS Western Region
WRP	Weather Research Program
WSFO	National Weather Service Forecast Office
WSO	National Weather Service Office
WSR-57	Weather Service Radar, 1957 version
WSR-74	Weather Service Radar, 1974 version
WWW	World Weather Watch