NWS PROGRAM SURVEY

An Inventory of Technological Advances

National Weather Service
Office of Meteorology

May 1986

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1.0 INTRODUCTION

This report is an update of an assessment of the National Weather Service's (NWS) uses of technology in its mission, titled "Technology Assessment for the 1980's and Projections for the 1990's," which was produced by the NWS Office of Meteorology (OM) in 1981. It describes the effects on the overall NWS mission of the revolutionary technological advances of the early and mid-1980's, and it projects further applications of technological refinements to the NWS mission for the rest of the 20th Century. It is a compendium of NWS present and planned applications of technology that is current as of March 1986. In a sense, this report is destined to be outdated almost as soon as it is issued because of the rapidly evolving technologies used by the NWS to further its mission of producing accurate and timely warnings, forecasts, and services. Yet this report describes a significant accomplishment by the NWS to maintain the highest proficiency in its operations based on the timely and advantageous uses of technology, and it provides a perspective of our collective mission.

At the heart of NWS technical achievement is the use of computer-centered procedures to improve the accuracy and timeliness of its warnings and forecasts; to develop automated, reliable observation systems; to assimilate and analyze increasingly large volumes of data; and to maintain and drive extensive communications networks for product dissemination. The largest computers used by the NWS for its operations are those of the NOAA Central Computing Facility (CCF), which the National Meteorological Center (NMC) uses to produce its numerical weather prediction (NWP) forecast guidance and to do extensive research. These top-of-the line systems have advanced from the Control Data Corporation (CDC) 6600 digital computer in 1970, to the IBM 360-195 system of the late 1970's, to the CYBER-205 class 6 supercomputer of the mid-1980's, and will lead to the future acquisition of larger computers with several orders magnitude more speed and capacity. Smaller computers have been quickly assimilated into NWS operations as well. Those used by the NWS include the Automation of Field Operations and Services (AFOS) minicomputers found at most field offices, the new automated upper-air stations, and the Automated Surface Observing System (ASOS). The Advanced Weather Interactive Processing System of the 1990's (AWIPS-90) will especially capitalize on minicomputers. Finally, the proliferating use of "personal" microcomputers has now been virtually taken for granted in NWS operations. Examples include forecast composition and transmission, data collection and assimilation, and the processing of many kinds of observations. In fact, the small computer will be an essential component of the planned upgrading of NWS operations for the rest of the 20th Century. This fact will repeatedly emerge in the later portions of this report describing the many current and planned technological programs of the NWS for hydrometeorological observation, data collection and assimilation, product creation and display, and dissemination.

2.0 ATMOSPHERIC OBSERVATIONS

Measurements of meteorological and hydrological parameters such as temperature, moisture, pressure, wind, and rainfall, are basic to the production of forecasts and warnings. These quantities are also the cornerstone of climatology. The NWS will continue to support observation programs which provide increasing knowledge of the atmosphere. It will, however, seek to make observing processes more efficient and less labor-intensive through automated techniques and focus upon the roles of individual observing systems within a composite network. Some developments in automated observational techniques will be discussed in the next several paragraphs.

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 recent advances in technology. This is rather critical since more observational data will be required in upcoming years, especially in remote or hard-to-staff areas, as the NWS seeks to focus on subsynoptic scale weather systems which often may not be adequately detected by the current observational network.

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 the NWS and the Department of Agriculture; NWS, U.S. Geological Survey (USGS), and Corps of Engineers (COE) gauging sites; NWS, Federal Aviation Administration (FAA) and Department of Defense (DOD) surface aviation reports; 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 the 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. The NWS, in its attempts to modernize and streamline its operations, is involved in a number of efforts to address these concerns.

The NWS and the 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 the 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 GMT to 1200 GMT) 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-tone into a minicomputer. Other automation efforts are being led by Federal and state agencies which operate hydrologic observing networks, two of which are the COE and the U.S. Geological Survey (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 3 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 6-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 the 6-hourly NWS requirements, communications problems have often developed in part because of the volume of data flowing to RFC's 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 the NWS, particularly during major flood events when up-to-date information must be relayed to the NWS River Forecast Centers (RFC's) 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 RFC's because only new information is sent from the gauges; the required synoptic 6-hourly data for forecast model input can be interpolated with sufficient resolution from the event-generated observations. An additional 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 ASOS program (section 2.1.5) will enable increasing amounts of automated observational data to be disseminated every hour via AFOS. These automated data will also be available to the RFC's 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 the FAA; the other will be operated by the DOD. The FAA has agreed to supply backup data of the same frequency and quality as from the ASOS network. The DOD will supply their data at the 6-hourly 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 locally-based system comprised of: volunteers; rainfall, river, and other hydrologic gauges; hydrologic models; a communications network; and a community flood coordinator responsible for issuing warnings. LFWS's may be manual or automated. About 900 LFWS's are operating as of late 1985, in addition to the 3,100 communities for which the 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); the NWS simply does not have the resources to provide specialized services for so many communities. The 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 LFWS's.

2.1.2.1 Manual LFWS's

Most LFWS's are of this type, consisting 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 LFWS's

Recent technological advances and decreasing costs in computerized systems have sparked a steady growth in automated LFWS's, especially those produced by private vendors. Three systems have evolved so far.

Flash Flood Alarm Systems (FFAS): Flash flood alarm systems 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. FFAS's may be part of both manual and automated LFWS's.

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 12 minutes.

Integrated Flood Observing and Warning Systems (IFLOWS): The 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 mentioned. 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 rainfall or river-level 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 the 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 and about 1,200 to 2,000 criteria-initiated observations sent daily by some 750 observers. It is based on experience with agricultural observer networks. ROSA 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. At this time there are no plans to expand ROSA to other areas of the country.

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), 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/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 almost completely. To seize the opportunity presented by these advances, the NWS has established the Automation of Surface Observations Program (ASOP). Its goal is to implement the Automated Surface Observing System (ASOS) at all NWS primary observing stations.

ASOS will handle routine observing and record-keeping functions, reducing the time spent by personnel in taking observations. This increased level of automation will allow the NWS to meet increasing demands for airport weather observations without adding staff. By providing a continuous weather watch and standardizing visibility and sky condition observations, ASOS is expected to contribute to improvements in warnings, forecasts, and aviation safety. ASOS capabilities will be evaluated during the Kansas Pilot Project (KaPP) and Climatic Test-Bed demonstrations (sections 2.1.5.1 and 2.1.5.2), which will provide operational and technical experience to reduce the risk associated with follow-on production system procurement. Production of ASOS for nationwide use is set to begin in FY 1988, with implementation over the following several years. About 250 ASOS are expected to be in operation by the early 1990's. The FAA is also developing its own Automated Weather Observing System (AWOS), which will provide a similar but somewhat lesser capability as ASOS for its observation sites. About 400 AWOS sites will be deployed between FY 1988 and FY 1992, according to current estimates; they will be installed mainly at small airports without control towers.

The NWS, FAA, and components of the DOD have interdependent observing programs; thus, efforts at automating observations have shown a need to be coordinated. The Joint Automated Weather Observing Program (JAWOP) has been established to coordinate observing policy, sensor development and implementation planning among the agencies. Coordination of JAWOP efforts are being accomplished by the JAWOP Council. The Council is chaired by the Federal Coordinator for Meteorology and comprised of policy level representatives from each participating agency. It addresses issues such 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. In addition, a JAWOP Action Group has been established to implement the guidance and direction set by the Council.

2.1.5.1 Kansas Pilot Project (KaPP)

The Kansas Pilot Project is a demonstration involving prototype ASOS installed at the six primary NWS observating locations in Kansas. The sites, some fully automated and some augmented by observers, were instrumented in mid-1985 and operate in addition to the current mannual observing operation at these sites. The KaPP is a model for future observing and forecasting operations using automated observations. It provides a means to evaluate various trade-offs between levels of automation and degrees of augmentation necessary to provide high quality observational information to forecasters, pilots, and other users. The KaPP will also provide experience in maintenance and logistics support as well as assess the effect of automation on communications and archiving.

2.1.5.2 Climatic Test-Beds

In this program, ASOS systems will operate in widely differing climatic regimes. Its purpose is to uncover weather-related problems associated with sensors or with NWS-developed algorithms that may limit their use. Test-bed sites have been established in the mid-Atlantic area (Richmond, VA), interior Alaska (Fairbanks), the maritime West Coast (San Francisco, CA), and the southeast U.S. (Daytona Beach, FL).

2.1.6 In-Situ Coastal and Marine Observations

Successful 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 globe 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 the NWS are described in which efforts are being made to provide improved weather observations over the oceans.

2.1.6.1 Ship Observations

Until the 1970's, commercial ships were virtually the only source of weather observations on the high seas. Ship reports continue to be an important element of marine weather analysis and forecasting since 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 the various observational programs that depend on automated or satellite sensors. The NWS will continue to require ship reports for all of its marine warning and forecast programs.

The international Voluntary Observing Ship (VOS) program, using the general structure and the observational codes recommended by the 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.

These ship reports are communicated to collection centers (and ultimately to 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 a 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 DOMB's 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 operate in the Great Lakes. This system began with the experimental buoy program of the early 1970's in combination with other existing and planned marine data systems, and it represents a sizable contribution to the NWS warning and forecast services with the U.S. 200-mile economic zone. DOMB's are significant portions of the database that is part 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 DOMB's particularly to complement ship and satellite data.

2.1.6.3 Coastal Marine Automation Network (C-MAN)

The NWS makes use of marine reports from 172 U.S. Coast Guard stations. These sites range from fully automated stations to manned locations. These data flow through a high-speed collection network to the NWS, which disseminates the reports as collectives via AFOS. Coast Guard stations have provided weather observations to the NWS for decades; the Coast Guard allows the NWS to install automated observing systems at its sites. New automated observing sites are also being added. 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 LNB's 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, the 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. Before 1979, the oil companies considered weather observations proprietary data, and none were released to the NWS. Data from GOWON are collected by the NWS via several computer interfaces from the oil companies. The GOWON has greatly improved the NWS's ability to forecast in the northern Gulf of Mexico; private meteorologists and oceanographers have also benefited. The GOWON sites are furnished with personnel, equipment and maintenance by the individual companies. The success of GOWON has allowed a network of buoys, platforms and island stations to be developed 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 (DRIBU)

The DRIBU is an inexpensive device that provides reliable wind, pressure, air temperature, SST, and ocean-current data. It is ideal for collecting data from ocean areas not regularly transited by ships and unfeasible for a fixed-buoy network. DRIBU's have proved their utility during several research and forecasting activities beginning with the First GARP Global Experiment (FGGE) in the late 1970's, as well as operational deployments in the subtropical Atlantic and Pacific Oceans.

A DRIBU is designed to report data for about 1 year via polar-orbiting satellites. DRIBU's figure prominently in the future NWS marine observational network because of their reliability and cost. About 120 are expected to be deployed globally in 1986. Special efforts are being made to enhance DRIBU 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 1988 and FY 1989, 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. ASOS sensors can detect thunderstorm electricity in their vicinities. But beyond the fact or 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. Recently, there has been a concerted effort by the NWS to determine the areal extent, distribution, frequency, and intensity of electrical activity in thunderstorms and to attempt to evaluate its utility in the NWS mission.

NWS efforts at lightning location methods date from the early 1960's, 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 the BLM and other land management agencies to detect lightning-caused wildfires; but the NWS has been able to obtain the lightning-stroke data on an experimental basis for its forecasting operations. The ALDS network consists of 12 position analyzers and about 30 direction finders, which have 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 2 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 Headquarters in Salt Lake City, UT. The processed data are sent from there to the Western Region (WR) AFOS loop. Data consist of mapped stroke location and intensity; the intensity is available in both digital and contoured forms. These data were available only to WR Headquarters in 1982, but since 1983 they have been distributed to all WR WSFO's and WSO's, and may be accessed throughout the AFOS network.

The ALDS data have been useful to the NWS in a number of ways. In the Western Region continuous areal radar coverage is not available due to the presence of mountains; hence, there are significant operational problems in determining or even locating weather-producing systems using radar. ALDS has helped forecasters to distinguish thunderstorms from nonthunderstorm 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 in the WR has been established in the eastern U.S. Its coverage extends from Florida through New York and most of New England. The 10 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 via the Eastern Region AFOS loop. The 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. The NWS is exploring plans to work with BLM, DOD, FAA, and other agencies to establish a national network of lightning detection systems.

2.2 Upper-Air Observations

The rawinsonde network is the foundation of NWS upper-air analyses and forecasts. It will continue to be since it is the most accurate source of atmospheric data. Data from automatic remote sensors -- Profilers and satellites -- will become more important with time because of increasing availability and reliability of these data through the 1980's and 1990's.

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 1940's and 1950's, 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 the current upper-air tracking systems. It will replace outdated subassemblies with solid-state modules and other equipment to allow automatic operation. Full automation will result from computer software that will recognize the meteorological data transmitted by a time-commutated radiosonde. This software is being field-implemented; the ART hardware will be implemented by the end of CY 1986.

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 1960's 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 Great Britain. 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. The NWS furnishes personnel, and Canada provides maintenance and expendables. NWSH is involved with the United Nations World Meteorological Organization (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 coverage by ASAP include routes between the U.S. west coast and Alaska and routes to the Panama Canal, to Hawaii, and points in the Far East.

2.2.3 Atmospheric Profilers

The NOAA Environmental Research Laboratories (ERL) have since the late 1970's been investigating the use of automated sensors to determine vertical variations of temperature, moisture, and wind. Their research led to the development of prototype surface-based upward pointing sounders known as Profilers. A number of them 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 the NWS and other agencies in developing new observing and forecasting systems. Two types of Profilers are under development, thermodynamic and wind Profilers.

The thermodynamic 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 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 for contribution to improve NWS warnings, forecasts, and services. Examples of these contributions 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.

The Wind Profiler Demonstration Project (WPDP, section 6.3) will operate a network of 30 wind Profilers in the Midwest beginning late 1988 and continuing through 1992; their data will form the input for as-yet-undeveloped mesoscale numerical forecast models. This Wind Profiler Demonstration Network (WPDN) will be used to provide information to NOAA Management for establishment of a nationwide operational network of wind Profilers in the 1990's.

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 1960's. 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 1970's, as part of the enlarged observation network for the First GARP Global Experiment (FGGE), a device called the Aircraft to Satellite Data Relay (ASDAR) 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 1 C^{o}. Thus ASDAR can produce a high-density set of reliable wind and temperature observations to be sent to a meteorological processing center within 1-2 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 being developed by a WMO-coordinated consortium of meteorological services will add the capability of providing turbulence and maximum wind data and is expected to be completed in 1987. International carriers of the consortium members will have units installed. The 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 65 to 85 ASDAR units in operation by the early 1990's.

The principal limitations of the ASDAR system are that the meteorological information is observed primarily at a single level, and that profiles are concentrated near major airports; but the main advantage is that a substantial deployment of ASDAR units on commerical aircraft will 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 Aeronautical Radio (ARINC) 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 2 or 3 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. To bring this about, the value of large numbers of aircraft reports must be clearly demonstrated to airline management and avionics manufacturers.

2.2.5 Satellite Remote Sensing of the Atmosphere

Meteorological satellites have been providing 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 available. At this time, the NOAA-6 and NOAA-9 polar satellites provide temperature and humidity soundings as well as imagery. However, only one geostationary satellite, GOES-6, is available for imagery and sounding data, and the two-GOES satellite system is not likely to be restored until mid-1986. Although coverage from one satellite is not optimum for NWS needs, the GOES-6 satellite has been seasonally moved between 98° W and 108° W to provide the best possible coverage for the various NWS major warning and forecast programs.

NWS operational use of satellite data in forecasting began in the mid-1960's when NMC began to routinely use 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 by NESDIS' predecessor, the National Environmental Satellite Service (NESS), at Washington, D.C., 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 in the form of film loops to the WSFO for the station's warning and forecast program. In 1974, NESS established three more SFSS's, at Miami, FL, (collocated with NHC); Kansas City, MO, (collocated with NSSFC); and San Francisco, CA, (collocated with the San Francisco WSFO). At that time, the SFSS's began to be conduits for GOES satellite imagery sent via high quality telephone lines to all WSFO's within the SFSS's area of responsibility, and to a steadily growing number of other users, both in the Federal Government and in the private sector. As of 1986, this basic service is still the main data-relay service of the SFSS's, which now total 7 in number. (SFSS's were established at Anchorage, AK; Honolulu, HI; and New Orleans, LA, in the late 1970's. Since 1984, SFSS's have been part of the NWS.) All SFSS's, as indeed all WSFO's, rely increasingly on electronic forms of data presentation. A video disc system produces up to 24 hours of data in animated sequences (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, but computer-produced sequences are readily available to users that have devices manufactured by the private sector.

2.2.5.1 Satellite Imagery

Imagery from satellites continue to be the most important product from the satellites. From the earliest TIROS images supplied by onboard TV cameras, imaging technology has progressed to its current state as used by the geostationary and polar-orbiting spacecraft of the mid-1980's. The GOES-6 satellite sensor is the VISSR Atmospheric Sounder (VAS), which has 3 operating modes:

- o the Visible/Infrared Spin Scan Radiometer (VISSR) mode, which provides "conventional" visible and IR imagery of the full-earth disc every half-hour, or of smaller areas at more frequent intervals;
- o the multispectral imaging (MSI) mode, which can provide visible and up to four simultaneous IR images selected from the 12 IR channel of the VAS; and
- o 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 every 3 hours, are processed, sectorized and enhanced at NESDIS's Central Data Distribution Facility (CDDF) in Camp Springs, MD, and are relayed by the SFSS's to their users. Visible and IR imagery produced as often as every 5 minutes over small areas are sent to NSSFC and NHC, to support continuous monitoring of rapidly developing severe weather or tropical cyclone activity. The availability of animated imagery is limited at this time to only those NWS elements collocated with SFSS's or those having MCIDAS terminals (NHC, as well as NSSFC with its Centralized Storm Information System (CSIS)). The Satellite Weather Information System (SWIS; see section 4.2) will provide basic imaging capabilities to WSFO operations. VAS Data Utilization Centers (VDUC, section 4.5) will have sophisticated imaging capabilities and are scheduled to be installed at National Centers.

Imagery from the Polar Orbiting Environmental Satellites (POES) has a very important use in NWS field operations. Since polar orbiters were technologically feasible for many years before geostationary satellites, the 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. As of 1986, NOAA-6 and NOAA-9 provide visible and IR imagery by means of their Advanced Very High Resolution Radiometer (AVHRR) sensor, by limited direct readout or (more commonly) to the users of GOES imagery served by the SFSS's. Over high latitude areas such as Alaska, the 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 the problems of 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 1970's and have become an important part of operational synoptic upper-air analysis (and, by logical extension, numerical weather prediction). 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 been a more recent development, paralleling the development of geostationary satellite technology that came several years after polar satellites. 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, processed at the University of Wisconsin's Space Science and Engineering Center (SSEC), are received via MCIDAS terminals at the 3 National Centers and 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. Newer NWP models will use VAS data for test runs during the winter of 1986-87. 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. The deployment of GOES I-M with its 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 the continued refinement of geostationary sounders. Satellites like the GOES produce real-time data every half hour or oftener, in contrast to conventional sounding data from rawinsondes every 12 hours. Also, the unchanging perspective of the geostationary satellites allows constant monitoring of a weather event over a fixed area.

2.2.5.3 Satellite-Borne Lightning Detectors

Detection of lightning in weather-producing 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 the 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/NASA team is investigating the suitability and cost of including a lightning detector aboard a GOES satellite. A report from this team is expected in spring 1986.

2.2.5.4 Remote Sensing of Marine Surface Winds by Satellite

The surface wind over the ocean produces the stress that leads to waves and swells, the sea conditions that affect shipping interests. A consistent, reliable definition of the surface wind field is essential in providing useful sea-state information to users. The NWS currently uses observations from the VOS ships and buoys to estimate the wind field and deduce the sea state. Obtaining information on sea conditions using polar-orbiting satellites has been a promising idea since the short-lived 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 DOD U.S. Navy's Remote Ocean Sensing System (N-ROSS) satellite, scheduled for launch in mid-1989, will carry a scatterometer designed to measure wind speed and direction near the surface. NWS operations of the early 1990's envision the ability to use N-ROSS data.

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 the 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's 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. By late 1986, a program will be under way in which NWS, NESDIS, and the U.S. Air Force will share certain satellite products and services.

The next series of geostationary meteorological satellites, GOES I-M, is already under development. A contract for these satellites has been awarded, and the first satellite in the series is expected for deployment around mid 1990. GOES I-M will offer the following improvements to the current GOES sensor technology: increased IR resolution and number of channels; relocatable scanning of areas; independent imaging and sounding capability; better navigation; and increased thermal accuracies 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, the first of which is expected around 1990. 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 (see section 2.2.5.2). AMSU-produced temperature soundings will be, up to 30 km altitude, at least as accurate as current POES TOVS sounders (1.5 K^o accuracy for IR (SSU) soundings and 3 K^o 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 5 water vapor channels on the AMSU compared to 4 on the MSU, including 3 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 British Meteorological Office. Technologies required to develop these sounders have not been developed or cannot be tested as yet. Similarly, the NASA WINDSAT project, which calls for the use of lidars on polar satellites for vertical wind profiles, will not be feasible until well into the 1990's.

2.3 Radar

For more than 30 years, weather surveillance radar has been the sine qua non of the NWS warning and forecast services, particularly in regard to severe local storms monitoring. Radar will be even more essential in the future as one of several improved technological capabilities to be used 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 manually produced digital hourly observations are composited by computer into a national summary chart.

Maintaining the NWS radar network in the pre-NEXRAD time period will be accomplished by a combination of interim measures to sustain the current net, 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/display capabilities, to meet DOT needs; these improvements will upgrade the NWS network coverage as well. NWS interim measures consist of replacing 7 of the worst-condition WSR-57's 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) 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 continuous 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 RADID (Radar Information Display) terminals allow users to dial up RRWDS sites and display up to four images at once, loop up to 8 images, and zoom in on nine sectors of the normal PPI display.

A total of 100 RADID terminals have been installed, with 2 each going to NMC, NHC, and NSSFC, and the rest to RFC's, most WSFO's and some WSO's with 24-hour warning responsibility. The FAA has installed RRWDS receivers at all CWSU's and EFAS sites; 3 WSFO's use RRWDS receivers. WSO's with warning responsibility that did not receive RADID's 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 the Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT), and will present many kinds of information about hazardous weather to enhance the ability of the NWS, the military, and the FAA to support their operational mission requirements. It is expected to be the NWS operational radar system of the 1990's. 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 benefits beyond those of the current network capabilities, 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. 113 will be operated by NWS and 23 by DOD in the 48 contiguous states, with the rest distributed through Alaska, Hawaii, and DOD and FAA installations in other parts of the world. Operational implementation is set to begin in 1989 and end in 1993.

3.0 COMMUNICATIONS

Advances in communications technology over the last decade have paralled advances in computer technology. The NWS has made extensive use of technological advances in both fields, so that it is now rare for operational NWS products to be composed and disseminated within the NWS by nonautomated and noncomputerized means. The process of composing and transmitting a forecast, for example, has been revolutionized. As late as the mid 1970's, 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, but more importantly it was time-consuming. In the case of warnings, the process could significantly reduce the warning's lead time and hence its potential effectiveness. In the mid 1980's the entire process from message composition to receipt by the user has been greatly speeded up with the introduction of automated and computerized communications facilities.

3.1 Teletypewriter circuits

The NWS use of teletypewriter circuits for communications, data collection and product dissemination within the U.S. is declining. The mid 1980's has seen the demise of a number of teletype circuits, such as Rawarc for collecting radar reports, that NWS had used for many years. Teletypewriter circuits are still used by the 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 1970's, 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 WSFO's and WSO's, all state distribution circuits. SMCC also is the AFOS communications interface to NMC, to other NWS units not considered field offices, and to networks for data acquisition and communications external to NWS.

As of early 1986, all WSFO's in the conterminous U.S. and the majority of WSO's have the AFOS system. The Alaska and Pacific Region WSFO's and WSO's are linked 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 for permanent display. Products can be stored for extended periods and 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.

As of 1986 AFOS has approached its limit for data transmission capabilities. Improvements to AFOS, known as System Z, are planned for the late 1980's. 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 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 Spring and Suitland, MD. The data are sent to field sites via AFOS and RJE links. The primary NWS use of the GOES DCS is the collection of hydrometeorological and oceanic data; the DCS also is used for remote calibration of the DCP's. NOAA maintains 703 DCP's on data buoys, river-gauging sites, and remote observing sites, out of a total of 4,803 DCP's using the GOES DCS. The NWS uses about 75 percent of the 4,803 DCP's in river-stage and flood forecasting, collecting routine reports every 1 to 6 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

To upgrade satellite communications capabilities, NESDIS has initiated the NOAAPORT program, which will replace the data-distribution function of the CDDF (section 2.25.1) with a point-to-multipoint satellite broadcast system. NOAAPORT is being closely coordinated with the NWS AWIPS-90 program but will benefit all of NOAA. The program will use domestic communications satellites and readout terminals installed at user locations. NOAAPORT will be implemented in three phases: Phase I, set for mid 1987; Phase II, in early 1988; and Phase III, scheduled for 1990. GOES-TAP analog data will be broadcast in Phases I and II but will be gradually replaced by full-resolution digital GOES data by the time of Phase III. Data from AFOS (including System Z) will be sent during Phases I and II; AWIPS-90 data are expected to replace the System Z data beginning in Phase II. GOES DCS data will begin to be distributed by NOAAPORT in Phase II.

3.3.3 Polar Orbiting Operational Environmental Satellite (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 further processing 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 1990's.

3.4 Advanced Weather Interactive Processing System for the 1990's (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 in part 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:

- o 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;
- o the Field Distribution Network (FDN), for exchange of locally produced forecasts and warnings and of locally taken observations including NEXRAD, surface, and upper-air observations;
- o 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 remote-job entry (RJE) from NC's and RFC's 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 Central Weather Support Units (CWSU) collocated with FAA facilities. The variety of external interfaces will be further complicated by the requirements of individual AWIPS-90 sites and by the fact that many of the major programs of the NWS 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 the NWS to determine efficient ways to process data and extract information quickly, both at field forecast offices and at National Centers, 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 already reaching a state of development that threatens to overwhelm the present NWS data processing and communications capabilities. A series of 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 is capable of overlaying up to 3 graphical products having the same map background and displaying the combined product. AFOS is not, however, capable of animation, or of processing or even displaying high-resolution data such as from radar or satellites. AFOS has been the first step in the development of NWS operational interactive processing systems, and will be enhanced by some transitional systems; improved NWS interactive processing capabilities will culminate in AWIPS-90.

4.2 Satellite Weather Information Service (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 micro-processor 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 will provide the user with the capability to color-enhance the display data. Up to 16 enhancement curves can be stored in SWIS. Fifty-five SWIS's will be procured with installation at all WSFO's by early 1988. The SWIS program is intended to serve NWS operationally into the early 1990's until AWIPS-90 is in place.

4.3 Centralized Storm Information System (CSIS)

CSIS is based on MCIDAS (section 2.2.5.2), the interactive processing system developed by the University of Wisconsin. The National Severe Storms Forecast Center (NSSFC) has used CSIS since 1982. CSIS interactively enables forecasters to assimilate large amounts of satellite and conventional data, to get 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 the 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 and is expected to remain in use until the NSSFC VAS Data Utilization Center (VDUC, section 4.5) is deployed. CSIS is another intermediate system bridging the gap between the present and future operations of the NWS and providing information on functional requirements and performance specification for the AWIPS-90 interactive system. It will be replaced in FY 1987 by a 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 is developing 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 1990's. Two workstations are operating at this time at the PROFS facility. A PROFS workstation is planned for WSFO Denver in October 1986 as part of DAR^{3}E (section 4.6.1). In addition, data from PROFS are available to the FAA's Central Weather Support Unit (CWSU) at Longmont using an older version of the PROFS workstation. Valuable experience in real-time interactive use of data has been gained by exercises conducted at PROFS involving field personnel as well as evaluations by CWSU personnel. 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 the definition of requirements for the AWIPS-90 system.

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 are processed by the SSEC at the University of Wisconsin and received at NSSFC, NHC, and NMC via MCIDAS. These processed 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 demonstrated 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 the National Centers (NC's) and used operationally. Its development will be closely linked to planned NWS AWIPS-90 development activities. NMC's VDUC is expected to be operational by November 1986, and the VDUC's for NSSFC and NHC are expected to be implemented by late FY 1987.

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

The communications capabilities of AWIPS-90 have already been described in section 3.4. Of equal importance 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 1990's.

By the time AWIPS-90 is fully implemented, the warning and forecasting functions of today's WSFO's and WSO's will reside at Warning and Forecast Offices (WFO's). AWIPS-90 will provide support for WFO warning and forecasting 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 allow for forecast techniques development, products and services evaluation, and scientific training for the WFO staff. In support for all of 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, thus allowing maximum flexibility and capability to support future analytical techniques, communications, information handling, and expansion.

AWIPS-90 capabilities will effectively 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 flow of 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 things as quickly as possible 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, the 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 1989 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^{3}E)

This exercise, developed in conjunction with PROFS, will begin in 1986 and will be focused on the field forecast environment (specifically WSFO Denver). 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 using workstations and software in a quasi-operational setting. There will be one, possibly two, experimental workstations which will replace one or two AFOS consoles at Denver WSFO during this exercise, providing AFOS capabilities along with the experimental ones; public and possibly aviation forecast products and services will be produced on the workstations. In particular, the exercise will operationally evaluate the workstations 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(s) 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)

This proposed program, which will begin limited operations in 1986, will seek to gain knowledge for use in refining and applying AWIPS-90 requirements and specifications, concentrating on hydrologic forecast services. It will be designed with the following goals in mind:

- o Develop techniques to handle and integrate automatically all hydrologic data for River Forecast Centers (RFC) and NWS offices with warning and forecast responsibilities;
- o Establish requirements and develop programs for a local data base;
- o Develop an initial version of a real-time interactive NWS River Forecast System, including data processing, river forecast models and guidance, and graphics capability;
- o Determine the most effective RFC use of the NOAA CCF;
- o Develop new archival and retrieval techniques for new data types;
- o Evaluate the use of two-way data exchange between RFC's and water resource agencies;
- o Help define new roles for coordination of hydrometeorological services among RFC's and the Area Forecast Coordination Units (AFCU) and the Warning and Forecast Offices (WFO) of the restructured NWS;
- o Evaluate the effects of system support requirements on the operational warning and forecast mission.

All of these activities are not possible at this time using existing systems within NWS or NOAA.

Two field sites have been selected as PROTEUS test facilities: the Missouri Basin RFC at Kansas City, MO, which will be developed first and which will be the primary development center for data management techniques and interactive modeling capability; and the Tulsa, OK, RFC, which will receive the data management software developed at the Missouri Basin RFC and will be the primary testing and development site for the integration of NEXRAD data into hydrometrological operations. The PROTEUS equipment at each site will consist of a high-performance multi-user virtual memory processor, several alphanumeric and color graphic workstations, high capacity mass storage media, hardcopy devices, and other equipment. The benefits of this project will be seen in the advanced interactive forecast techniques and data-handling procedures that will be developed, and in the functional requirements and systems specifications that will be incorporated into the AWIPS-90 prototype phase.

4.7 New concepts in Interactive Processing using Artificial Intelligence (AI)

The NWS, in its efforts to automate its field operations, is seeking to make the forecaster's decision-making processes easier. In particular, the 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 the 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 1990's, 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 years have brought about a radical change in the NWS methods of getting its products to its users. Around 1970, the primary methods of disseminating NWS products were by teletype circuits and, particularly 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 notoriously error-prone. Telephones to the weather offices were overburdened at the very times information was most needed. The NWS has developed a number of dissemination methods over the years which have led to more efficient dissemination of products and retention of the long-standing generally high esteem held by the public towards the NWS. Even better dissemination techniques are being planned as the 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 Service (NWWS)

The NWWS is a series of 51 data circuits -- mainly teletypewriter, but also FM carrier and satellite -- organized generally within individual states. The NWS enters its products at a WSFO or WSO on the individual circuit via AFOS, which also may drive the circuit; 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 3,500 subscribers are commercial broadcast radio and TV stations, cable TV stations, and state government agencies. NWWS is being upgraded to 300 bps for interstate circuits. An RFP for 1,200 bps satellite services has been drawn up.

5.1.2 NOAA Weather Radio (NWR)

The NWR provides continuous 24-hour weather broadcasts from selected NWS offices on 7 VHF-FM frequencies, from 375 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, the 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.

The 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. This concept is being tested at two sites in Maryland and offers great promise as a means of keeping travelers informed about changing weather 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. A large manufacturer of car radios will begin in the summer of 1986 to market radios with a NWR receiving capability.

5.1.3 NOAA Weather-by-Phone

The NWS uses 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. The NWS in most areas still disseminates warnings directly by phone to selected users. In cooperation with telephone companies in many metropolitan areas, the NWS provides forecasts and current observations 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. The NWS has undertaken a number of ventures with the private sector to provide cost-effective services that satisfy the dissemination needs of both the public and the NWS. One approach is being tested in Phoenix, AZ, in which a private company will operate a local weather-by-phone service using NWS products and bearing all costs.

Since 1981, the NWS has conducted two cooperative test efforts between government and private industry which have provided basic weather services and gauged the public's needs for weather information. A 90-day test conducted in Minneapolis, MN, during spring 1981 involved WSFO Minneapolis, the Offices of Meteorology and of Systems Development, and the Sperry Corporation, to provide 2-day forecasts for selected cities in the U.S. About 3,000 calls a day were received despite limited advertising and availability of the service. In June 1985, the 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 terrestrial 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 approximately 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 approximately 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 the NWS, FAA, DOD, and nongovernment organizations.

The NWS contracted with a private communications company in May 1985 to convert the two NWS terrestrial facsimile networks to satellite broadcast dissemination. This was accomplished as of March 31, 1986.

5.1.5 NOAA Family of Services (FOS)

Upon the implementation of AFOS, the NWS use of teletypewriter systems to disseminate its products to external users has virtually disappeared. In 1983 the NWS established the Family of Services (FOS), which is a means of access to NMC by external users to receive NWS warnings, forecasts and other products in real time. The FOS is a series of medium-speed communications services provided at Suitland, MD. The FOS has four separate services:

- o Public Product Service (1,200 bps), offering all public warnings, advisories, forecasts and services;
- o Domestic Data Service (1,800 bps), offering aviation forecasts and observations, as well as public, agriculture, hydrologic and marine warnings and forecasts;
- o International Data Service (1,800 bps), offering worldwide surface and U.S. upper-air observations;
- o NMC Numerical Products Service (4,800 bps), offering all NMC numerical guidance products out to 7 days, and selected forecasts prepared by European meteorological centers.

All the services are obtainable from the NWS for set user fees, and the private sector has provided value-added services for specialized users based upon the FOS information set.

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. The 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 regional portions of the nation. This program is funded by the 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 the NWS and cable TV companies in which the 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.

Newspapers, once the primary means for disseminating NWS weather forecasts, are now generally limited to being disseminators of post-event information. Most newspapers also include the climatological information and forecasts for their areas that are current at time of printing. The NWS has long enjoyed a generally cordial relationship with the print media and cooperates with them in every way possible especially whenever called upon to furnish interviews and background information in connection with news reports of weather disasters or unusual events.

5.1.7 Videotex Systems

The NWS has entered the age of the electronic bulletin board by making many of its products available to anyone with a telephone, a modem and a personal computer -- all for the price of a phone call. In 1983, the Washington, DC, WSFO developed, within the NWS, the first service of this kind, which is now called the Marine Information and Data Acquisition Systems (MIDAS). This service uses a host computer located at the University of Maryland to store a list of NWS products. These include marine warnings and forecasts along the U.S. east coast as well as public forecast products, which are compiled on AFOS, reformatted via PC, and retransmitted to the host computer. Current forecasts are automatically entered into the host computer every 6 hours; updated forecasts issued between regularly scheduled forecasts can be inserted manually. MIDAS has been very successful, and has spawned similar programs at WSFO's Boston, MA and Portland, ME.

5.1.8 Marine Radio Facsimile Systems

Radiofacsimile broadcasts of marine weather information were first performed 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 WSFO's 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. WSFO San Francisco prepares products for a larger marine area extending to the mid-Pacific; similarly, WSFO Washington's radiofax service includes most of the North Atlantic. Expansion of the regional program to include the Florida east coast, the Bahamas, and the Windward Islands will complete the system. In addition to NWS marine weather and oceanographic products currently being sent on the system, the NWS has asked the National Marine Fisheries Service (NMFS) and the National Ocean Service (NOS) to provide marine user-oriented products for facsimile transmission. The NWS radiofax program uses the radio transmission facilities of the U.S. Coast Guard, commercial marine radio stations, and academic institutions.

5.1.9 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/or 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 the 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 Operations

5.2.1 Voice synthesis technology

The NWS has been investigating methods of using to its advantage the rapidly developing field of voice synthesis technology to develop a computerized means of producing recorded messages for the NOAA Weather Radio. 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 difficult. It is not able to produce geographical names with their proper pronunciation, and its voice quality is relatively low. Synthetic speech has been used by the FAA in demonstrations to produce messages for pilot weather briefing. However, NWS is not considering synthetic speech for NWR broadcasts.

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 voice quality than synthetic speech; it is more human-sounding and less likely to offend the hearer with an artificial, obviously synthetic tone. The NWS has decided to use phrase concatenation speech technology in its consideration of computer voice response systems.

5.2.2 The NOAA Weather Radio Voice Synthesis Project

This project aims to provide a demonstration of phrase concatenation speech technology to produce automated messages for broadcast over NWR. In October 1985 the 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 the 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. Also being tested in connection with voice synthesis 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

The NWS will participate in a number of field experiments and demonstrations over the next decade 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 the NWS understand the small-scale processes; learn how to use the information provided by the experiments to improve warnings and forecasts; and determine the effectiveness of the various technologies involved in the projects. Specific examples of such projects are described below. Other opportunities will undoubtedly develop over the next decade.

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 is 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 proposed 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. More specifically, 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 STORM Project will divide the contiguous U.S. into three parts -- west, central, and east -- to establish three separate phases. The STORM-Central Program will be the first phase and will concentrate upon the Mesoscale Convective System (MCS), which is a beneficial rain-producer as well as a notorious originator of severe weather in the U.S. during the warm part of the year. The research goal will be to understand better the genesis, evolution, and structure of MCS's and to develop techniques to forecast (and hence warn of) these systems. STORM-Central is planned to operate in its most intensive phase from April through July 1990. The area under study will extend from the Gulf Coast to Canada and from the Rockies to the central Ohio Valley.

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, the National Severe Storms Laboratory (NSSL), the National Committee on Atmospheric Research (NCAR), NWS, and university groups to do field testing and evaluation of sensor systems, and to collect data on MCS's for research. The PRE-STORM project was conducted in May and June 1985. Its goals were: investigate the development, evolution and structure of MCS's; and, evaluate new sensing systems and develop observational strategies. The array of instruments used in PRE-STORM included:

- o NWS WSR-57's 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 2 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

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. The 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 mininetwork of three wind Profilers in Colorado beginning in 1986, followed by a formal setting up by the Wind Profiler Demonstration Project (WPDP) which calls for the establishment by late 1989 of a demonstration network having some of the expected characteristics of a national network. The 1986 Colorado mininetwork serves two purposes, viz: 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 a network of about 30 wind Profilers in the midwestern U.S. by late 1989 and continuing through the early 1990's. The configuration of the Wind Profiler Demonstration Network (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 mininetwork and later the WPDN, they will not be the only instruments sampling the atmosphere in those networks. The 1986 Colorado mininetwork will also include thermodynamic Profilers at each wind Profiler site as well as surface sensors; and the demonstration network of 30 wind Profilers will be enhanced by a limited number of thermodynamic Profilers and surface sensors.

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 much larger report than its predecessor of 1981 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, this report will be updated more frequently than before, probably on an annual 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, Systems Requirements Branch. 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

- Office of Scientific Development
  Hank Schmidt, Chief, Advanced Planning Staff

- Office of Technical Services
  Joe Facundo, Sounding Systems Branch
  Paul Hexter, Radar Program Leader
  Jerry Nickerson, Basic Observations Branch (Retired)
  Jon Parein, Basic Observations Branch

- Office of Meteorology
  Joe Conte, Services Integration Branch
  Rick Decker, Aviation Services Branch
  Marty Deiseroth, Systems Requirements Branch
  Ed Gross, Chief, Services Integration Branch
  Mary Heffernan, Systems Requirements Branch
  Ron Lavoie, Chief, Program Requirements and Planning Division
  Bob McLeod, Services Applications Group
  Henry Newhouse, Scientific Procedures Branch
  Gary Petti, Marine Products Branch
  Randy Racer, Chief, Services Applications Group
  Tom Reppert, Marine Products Branch
  Mike Young, Applied Services Branch
  Fred Zbar, Chief, Systems Requirements Branch

Finally, we thank Gale Jehle and Margery Hannon for typing the many drafts of this report.

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 Offices and Services
AHOS	Automatic Hydrologic Observation Systems
AI	Artificial Intelligence
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	Automated Radio Theodolite
ASAP	Automated Shipboard Aerological Program
ASDAR	Aircraft to Satellite Data Relay
ASOP	Automation of Surface Observations Program
ASOS	Automated Surface Observation System
ATS	Applications Technology Satellite
AVHRR	Advanced Very High Resolution Radiometer
AWIPS-90	Advanced Weather Interactive Processing System for the 1990's
AWOS	Automated Weather Observing System
BLM	Bureau of Land Management
bps	Bits per second
CATS	Conical Atmospheric Tropopause Sounder
CCF	Central Computer Facility
CDC	Control Data Corporation
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	Central Weather Support Unit
DAR^3E	Denver AWIPS-90 Risk Reduction and Requirements Evaluation
DCP	Data Collection Platform
DCS	Data Collection System
DIFAX	Digital Facsimile Network
DMSP	Defense Satellite Meteorology 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

DRIBU	Drifting Buoy
DS	Dwell Sounding
D/VIP	Digital Video Integrator and Processor
EDF	Experimental Data Facility (PROFS)
EFAS	Enroute Flight Advisory Service
EPA	Environmental Protection Agency
ERL	Environmental Research Laboratories
FAA	Federal Aviation Administration
FDN	Field Distribution Network
FEMA	Federal Emergency Management Agency
FFAS	Flash Flood Alarm Service
FGGE	First GARP Global Experiment
FOS	Family of Services
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
IBM	International Business Machines
ICRAD	Interactive Color Radar Display
IDE	Isolation Distribution Equipment
IFLOWS	Integrated Flood Observing and Warning System
INMARSAT	International Marine Satellite program
IR	Infrared
JAWOP	Joint Automated Weather Observing Program
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
MAREP	Marine Report
MCIDAS	Man/Computer Interactive Data Acquisition System
MCS	Mesoscale Convective System
METEOSAT	European Space Agency geostationary meteorological satellite
MIDAS	Marine Information and Data Acquisition System
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
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NESS	National Environmental Satellite 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
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
NWWS	NOAA Weather Wire Service
OM	Office of Meteorology
OWSE-NA	Operational World Weather Watch System Evaluation of the North Atlantic
PBS	Public Broadcasting System
PC	Personal Computer
POES	Polar-orbiting Operational Environmental Satellite
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
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

SSEC	Space Science and Engineering Center (Univ. of Wisconsin)
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 Service
TIROS	Television and Infrared Observation Satellite
TOVS	TIROS Operational Vertical Sounder
UHF	Ultra High Frequency
USGS	United States Geological Survey
VAS	VISSR (q. v.) 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
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
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR-57	Weather Service Radar, 1957 version
WSR-74	Weather Service Radar, 1974 version
WWW	World Weather Watch