THE ROLE OF THE MODERNIZED NATIONAL WEATHER SERVICE IN THE DEVELOPMENT OF A COASTAL OCEAN PREDICTION SYSTEM

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Abstract

The U.S. oceanographic community has initiated a major effort to develop a Coastal Ocean Prediction System (COPS) during the 1990s. COPS will require a denser, more sophisticated coastal meteorological observing network than the one which exists today. New observing systems associated with the Modernization and Associated Restructuring of the National Weather Service during the 1990s have the potential to provide much of the expanded observational data base needed for COPS.

This paper provides an overview of the proposed COPS, a description of the major new observing systems involved in the NWS modernization, and the role that these new systems and other NWS programs could play in the development and implementation of a national coastal ocean predictive capability.

1. Introduction

The National Weather Service has embarked upon a very ambitious and far-reaching modernization program which will continue through the 1990s. This program will include major restructuring of the NWS field organization in order to take advantage of recent advances in our ability to observe and understand the atmosphere. Improvements in data processing and communications technologies will also play a key role in making the Modernization and Associated Restructuring (MAR) possible (Friday 1988).

The NWS MAR involves the development of several new observing systems which will result in improved quality and timeliness of atmospheric observations, along with increased resolution and vastly greater volumes of data (including new types of data never before available in the operational environment). The primary new observing systems are: the network of WSR-88D Doppler radars—previously known as NEXRAD; ASOS (Automated Surface Observing System); GOES I-M, the upgraded Geostationary Operational Environmental Satellite series; and the wind profilers (ground-based atmospheric sounding systems utilizing Doppler radar technology). The WSR-88D and ASOS are actually tri-agency programs (Departments of Commerce, Defense and Transportation).

The tremendous amounts of new data would be of very limited practical use without adequate processing and communications capabilities. AWIPS-90 (Advanced Weather Interactive Processing System for the 1990s) is the integrating element of the MAR. It will be linked with the NOAAPORT satellite-based communications system which will disseminate the data collected and processed by AWIPS, and the products generated by AWIPS.

Recently, the U.S. oceanographic community initiated an effort to develop a national Coastal Ocean Prediction System (COPS) during the 1990s. Efforts to define exactly what COPS will encompass are still in the formative stages, but since the coastal ocean is greatly responsive to atmospheric forcing, an adequate coastal meteorological network will clearly be one of the required elements of COPS.

Although the primary purpose of the new observing systems and other technologies associated with the NWS MAR is to greatly improve the basic forecast and warning capabilities of the NWS, the new systems will also play an important role in the development and implementation of a future COPS.

This paper summarizes the major new observing systems, with emphasis on their potential roles in satisfying the needs of future coastal ocean prediction models. Also mentioned are a few other technologies and programs, both current and future, which should be of interest to COPS developers.

2. Overview of COPS

After nearly two years of preparation by the oceanographic community, a COPS Planning Workshop was held in New Orleans in the fall of 1989. The workshop was convened to follow the lead of the operational meteorological community by outlining a program to create a capability for coastal ocean prediction within a decade. The proposed COPS program is concerned with combining numerical models with observations (through data assimilation) to improve our predictive knowledge of the coastal ocean.

The idea of a coastal ocean predictive capability resulted from a growing awareness of the need to manage the coastal ocean wisely. The goal of the COPS Planning Workshop was to determine system requirements, and necessary research and development, for establishing an initial operational coastal ocean prediction system by the turn of the century (JOI 1990). Such an operational system will combine all available real-time physical data (through numerical models) to provide well-defined data products on a regular schedule and grid for the coastal ocean, and will disseminate the products to users. The workshop was sponsored by a number of government agencies, including NOAA, which is taking the lead in organizing an interagency group to address issues of common concern with respect to COPS.

From the COPS perspective, the term "coastal ocean" means the entire EEZ (Exclusive Economic Zone) plus estuaries and the Great Lakes. A two-level operational system is envisioned: (1) a course-grid (low resolution) model and observing system which will function continually throughout the U.S. coastal ocean; and (2) a "rapid-response," fine-grid (high resolution) model and observing system which can be activated for a particular area when it is needed (oil spills, search and rescue, etc.). The desired predictive capability is intended to address a variety of societal problems, including ship routing, trajectories for search and rescue operations, oil spill trajectory simulations, pollution assessments, simulation of the coastal ocean's response to climate variability, and a number of others (JOI 1990).

Despite the availability of technology and methodology for real-time reporting of key ocean variables, rarely are any of the present observational systems, with the exception of NWS's National Data Buoy Center (NDBC) buoys, equipped with real-time data telemetry. The present situation is unsatisfactory for fostering the development of predictive coastal ocean models, and cannot support an operational prediction system.

A greatly expanded real-time coastal ocean observational data base will be needed to satisfy the requirements of COPS (in both the development and the subsequent running of the predictive models). Data made available by the new observing systems and other technologies associated with the NWS MAR will comprise a significant portion of the expanded observational data base needed by COPS.

3. The New Observing Systems

a. The WSR-88D System

This network of advanced Doppler radars will provide measurements of atmospheric motions in addition to conventional reflectivity. About 155 WSR-88D systems are planned for the tri-agency program (Leone et al. 1989). The NWS will operate approximately 115 systems, while the Federal Aviation Administration (FAA) and Department of Defense (DOD) will operate about 40 (combined). The WSR-88D will generate numerous products (Pierce and Belville 1989) which will be of great benefit in detecting and tracking severe and potentially severe storms, but which will have many other uses as well (estimates/measurements of precipitation accumulation, atmospheric turbulence, wind shear, etc.)

Of particular interest to the marine community will be the VAD (Velocity Azimuth Display) wind product from the coastal WSR-88D sites. An example of a VAD wind plot is shown in Figure 1. A vertical profile of winds can be produced and displayed each time the radar makes a volume scan. The system then combines measurements of wind speed and direction from several elevations and times, and generates a time versus height cross section of wind vectors.

One of the primary anticipated usages of the VAD wind product is the timely determination of the boundary layer wind profile (which could aid in the computation of surface wind stresses over parts of the coastal ocean, leading to improved forecasts of significant wave heights). The usefulness of the VAD winds in this regard will depend on the distance from the radar of the area being sampled (range limitations), and on such factors as the thickness of the marine layer and the presence of enough tracers to produce a measurable return.

Coastal WSR-88D units will also enhance the marine warning program through improved ability to detect severe local

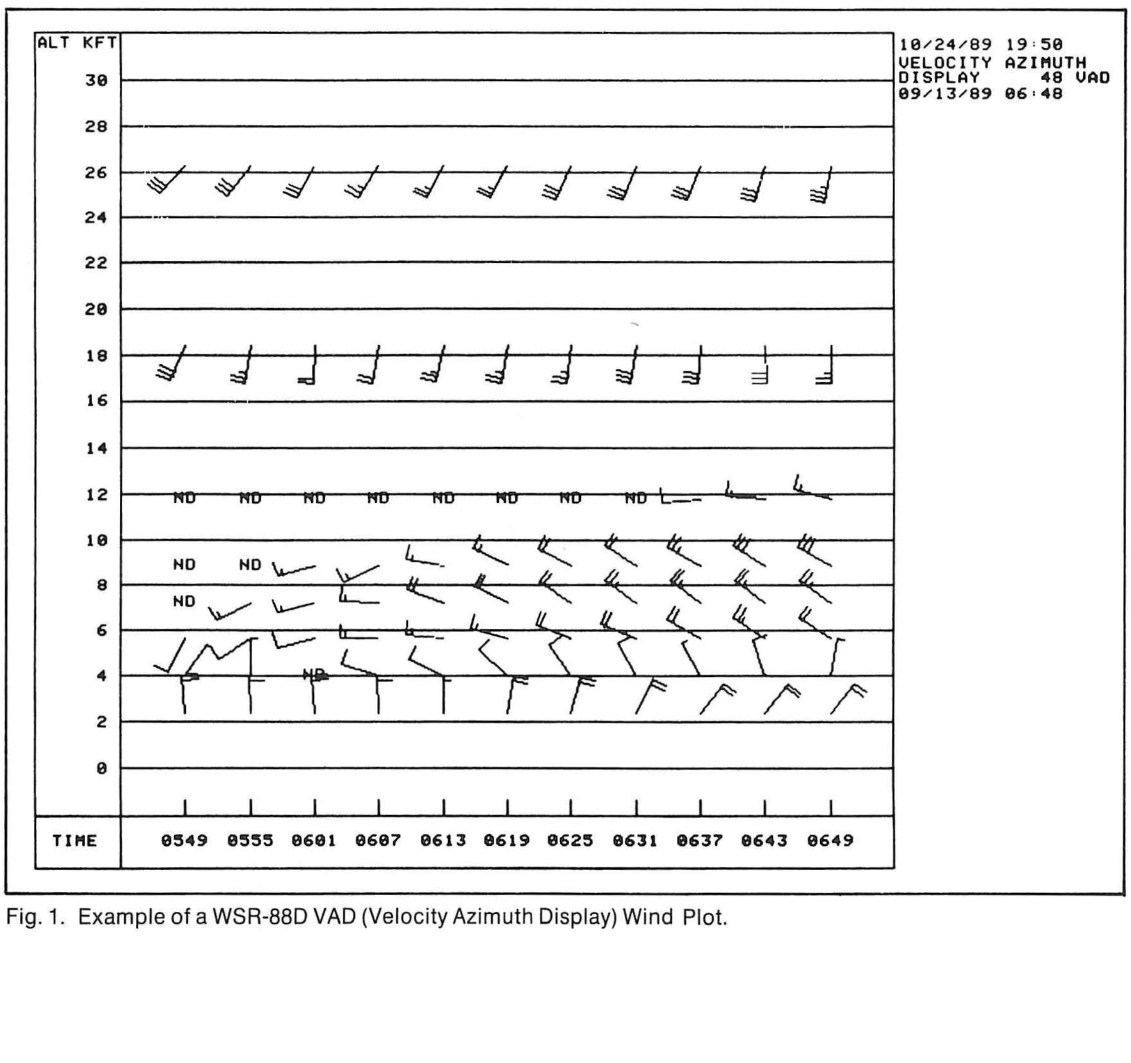

Fig. 1. Example of a WSR-88D VAD (Velocity Azimuth Display) Wind Plot.

storms (and resulting wind conditions). In addition, the WSR-88D has important implications for marine aviation, and for the oil and fishing industries. Figure 2 indicates NWS Southern Region WSR-88D sites with the anticipated installation dates. Note the locations of these units along the Gulf and South Atlantic coasts. Similar coverage is planned for the rest of the U.S. coastline.

b. ASOS

This system will take advantage of new sensor and computer technology developed over the past decade, making feasible the automation of surface weather observations. ASOS will help the NWS and FAA meet increasing demands for airport weather observations. The system will provide nearly continuous information on pressure, temperature, dew point, visibility, wind speed and direction, cloud coverage and heights, precipitation types and amounts, and most types of present weather (NWS 1989a). However, it cannot detect several important elements such as thunderstorms and related phenomena (hail, lightning), mixed precipitation, and clouds higher than 12,000 feet above ground level.

ASOS will observe, archive and transmit observations automatically, operating with or without observers. Over 1,000 systems may be acquired jointly by the NWS, FAA, and the Navy in the early and middle 1990s, including approximately 250 for the NWS, 85 for the Navy, and 600 to 800 for the FAA (NWS 1989a). ASOS will provide vital information for forecasters, pilots, air traffic personnel and others, and will provide it at many small airports where no such data are currently available.

ASOS systems will also be installed at a significant number of other locations across the country at which surface weather observations are not now available. Many of these sites will be on or near the coast, thus increasing the amount of coastal surface meteorological data available for use in developing a coastal ocean prediction system. Figures 3 and 4 indicate NWS and FAA observing locations before and after ASOS implementation.

c. Satellites

Meteorological satellites have provided reliable information for many years and are practically indispensable to the science and practice of meteorology. Future satellites will provide significantly improved information.

(1) GOES I-M

In 1992, NOAA plans to launch GOES-I, the first of a new generation of GOES satellites (NESDIS 1989). After the launch of GOES-I, the launches of GOES-J, -K, -L, and -M will follow at roughly two-year intervals on the average, but actual launch dates will depend on the operating condition of the satellites already in orbit.

Operational enhancements planned for the GOES I-M series include improved imaging and sounding capabilities (including better resolution and more frequent data transmissions), and a longer operational lifetime. The new satellites will have separate imaging and sounding instruments (Purdom 1988) instead of a single instrument which shares those responsibilities. Operational enhancements are expected to be refined and improved with each successive satellite in the GOES I-M series.

The imager will be able to view in five channels at the same time. The channels will include one visible, two infrared (IR), one thermal window and one IR water vapor channel (NWS 1989b). The resolution (at the sub-satellite point) of the IR channels and thermal window will improve from the current 8 km to 4 km, and the water vapor channel resolution will improve from 14 km to 8 km. The derived products from the imager will include at least two that will be of interest to ocean modelers—low level winds and sea-surface temperature (SST) composites (NWS 1989b).

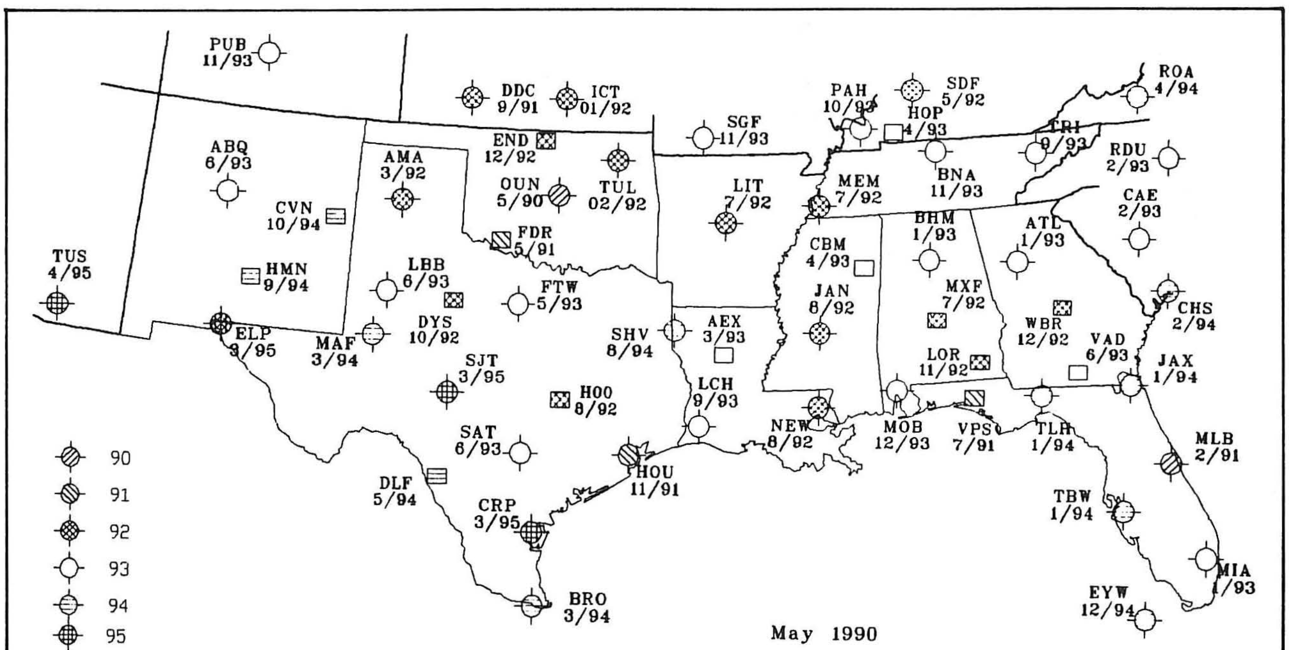

Fig. 2. Locations of WSR-88D Sites in the NWS Southern Region. The rectangular symbols denote Dept. of Defense WSR-88D sites. The numbers refer to the planned month/year of installation.

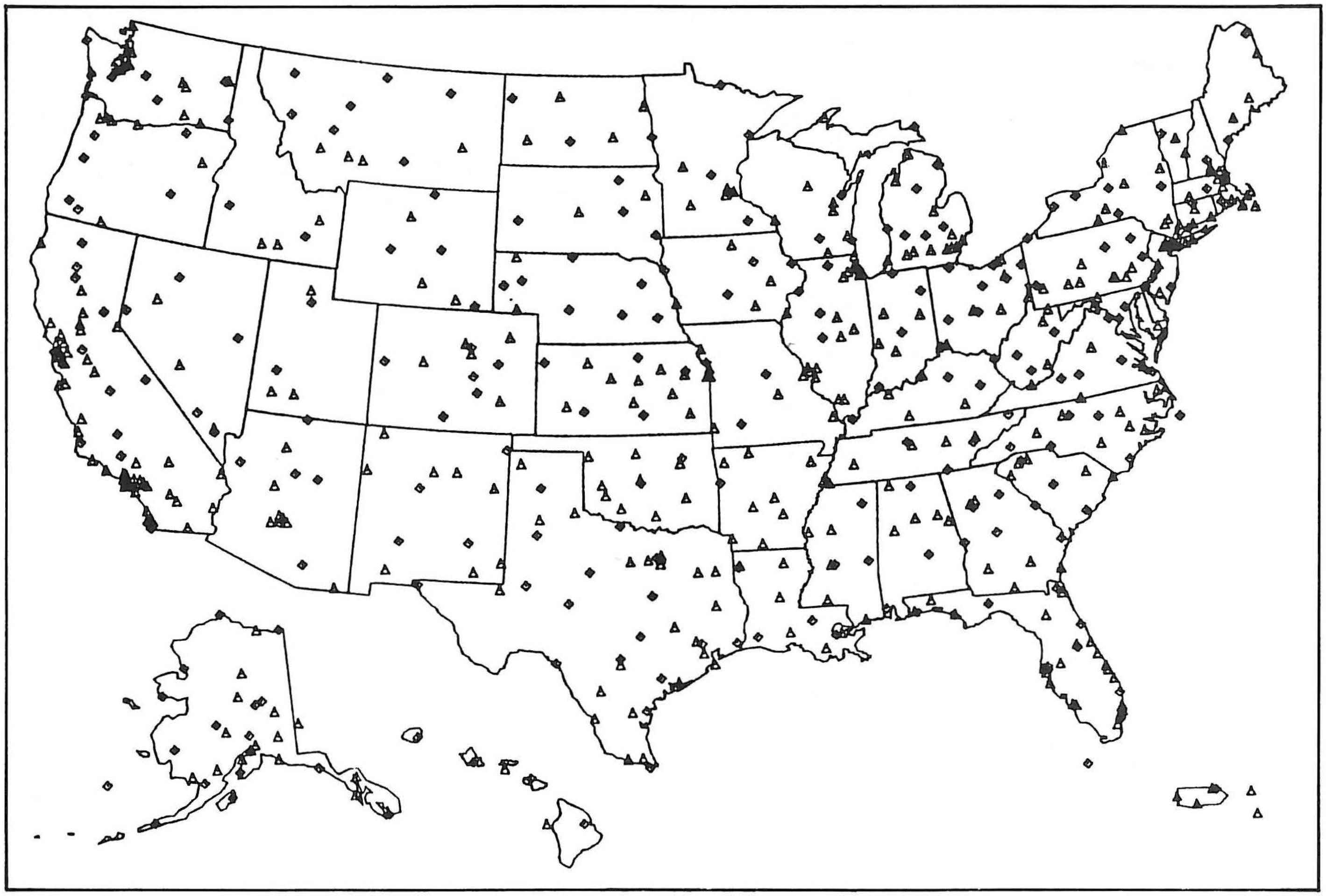

Fig. 3. Current NWS and FAA Observing Locations.

(2) Other Satellites

Other geostationary satellites used in NWS operations are Japan's GMS and the European Space Agency's METEOSAT. Data from ocean satellites of other agencies, such as DOD's Defense Meteorological Satellite Program (DMSP), will also be available.

Enhancements planned for the next generation of NOAA polar-orbiting satellites (NOAA-K, -L, -M) include improved AVHRR (Advanced Very High Resolution Radiometer) imagery (for SST fields), and an improved microwave sensor. The current 4-channel microwave instrument will be replaced by a 20-channel instrument, resulting in much better resolution, and a marked improvement in our ability to diagnose such features as hurricane/tropical storm intensity, frontal baroclinity, etc. (Purdom 1988).

In addition, the United States is planning to obtain remotely sensed wind, wave and sea-ice measurements from the European and Japanese polar orbiting satellites (ERS-1 and JERS-1) in the early 1990s. These satellites will carry Synthetic Aperture Radars (SAR) which will provide these measurements in all weather conditions (NWS 1988). Similar technology is planned by NASA for the mid to late 1990s through the Earth Orbiting System (EOS) Polar Platform. NWS operations in the 1990s envision the use of these instruments for improving ocean forecast guidance at the National Meteorological Center (NMC). Even though they will not be real-time, operational systems, a subset of the data suite may be processed and available to NWS National Centers and a few targeted field sites within 3 to 12 hours.

d. Wind Profilers

These are multiple-beam Doppler radar systems that detect fluctuations in atmospheric density, caused by the turbulent mixing of volumes of air with slightly different temperature and moisture content. The fluctuations are used as tracers of the mean wind. The profiler radars reflect their energy off fluctuations in the radio refractive index, created by turbulent eddies (van de Kamp 1988). The system then converts these signals to wind vectors. The profilers can even operate in the presence of clouds and precipitation, but the accuracy of the wind computations can be seriously degraded when convection or non-uniform precipitation is occurring in the area being sampled by the profiler (Brewster 1989).

The NWS is currently in the early stages of deploying a 30-station Wind Profiler Demonstration Network (WPDN) across the central U.S. (Fig. 5). Future deployment of profilers will depend upon results from the WPDN experiment, the purpose of which is to assess the utility of wind profiler data in both synoptic-scale and mesoscale weather analysis and prediction (Augustine and Zipser 1987). Unfortunately, none of the WPDN profilers will be located near the coast.

Also, one factor limiting the applicability of future wind profiler data to the modeling or prediction of coastal ocean

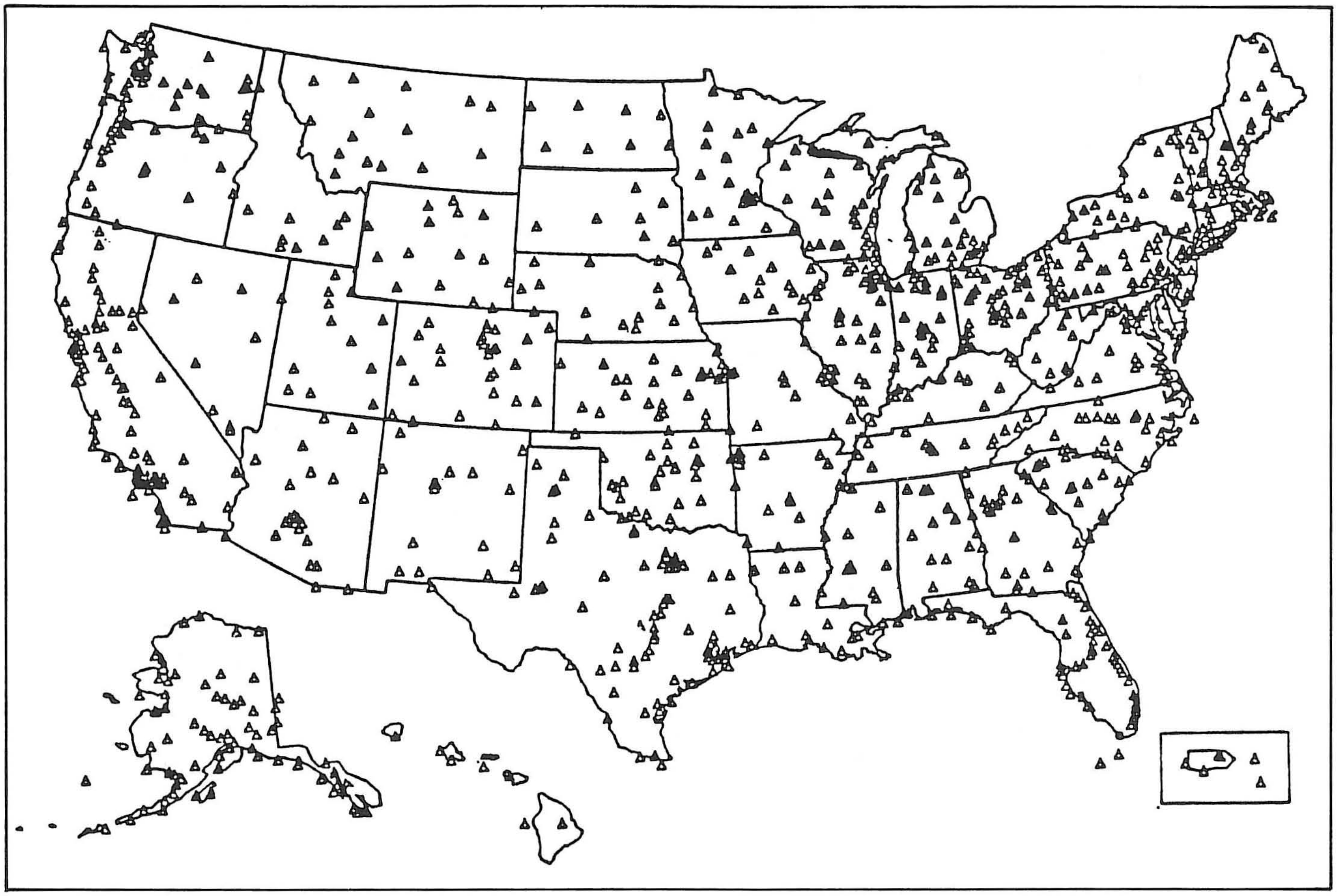

Fig. 4. ASOS Locations (NWS and FAA).

currents is the fact that the WPDN profilers cannot measure winds below about 500 meters due to internal electronic constraints (van de Kamp 1988). It is important to stress that profilers will only supplement—not replace—radiosondes, since the wind profiler cannot measure temperature and moisture profiles.

One possibility worth investigating is the development and testing of a modified version of a profiler which samples only the lowest 2,000 meters of the atmosphere (including the planetary boundary layer). Such profilers could be placed aboard moored buoys or offshore platforms to sample the low-level wind field in the coastal marine environment.

4. Other Technologies and Programs

A number of other NWS technologies, programs and products could play an important role in a future COPS. Several of these are considered briefly below.

a. AWIPS-90/NOAAPORT

When the NWS MAR is completed, the AWIPS system at each Weather Forecast Office (WFO) will integrate data from all the new sources and present the data to the forecaster as coherent information on a common display. AWIPS will provide interactive techniques to analyze, integrate and present weather information and to prepare forecast products. Future WFO locations are indicated in Figure 6.

The AWIPS/NOAAPORT satellite-based communications network will support the prompt distribution of data, analyses and forecast products to all NWS and NOAAPORT users.

b. C-MAN (Coastal Marine Automated Network)

The C-MAN program provides the NWS with reports from over 50 coastal stations (Fig. 7) which include U.S. Coast Guard (USCG) unmanned offshore platforms and lighthouses, offshore oil platforms, beach areas, and navigational buoys (JOI 1990). Additional reports come from manned USCG stations. The data flow through a high-speed collection network and data quality control system to the NWS, which disseminates the reports through its AFOS (Automation of Field Operations and Services) system.

Recently, NDBC and the oil industry began implementation of a network of four C-MAN stations in the northwest Gulf of Mexico. This program, the Meteorological and Oceanographic Monitoring System (MOMS), may grow to include more stations in the early 1990s.

c. Other Coastal and Near Shore Observing Systems

The NWS will continue to use observations from Voluntary Observing Ships (VOS) and NDBC buoys to collect data on wind, sea level pressure, air temperature, sea surface temperature, and sea state.

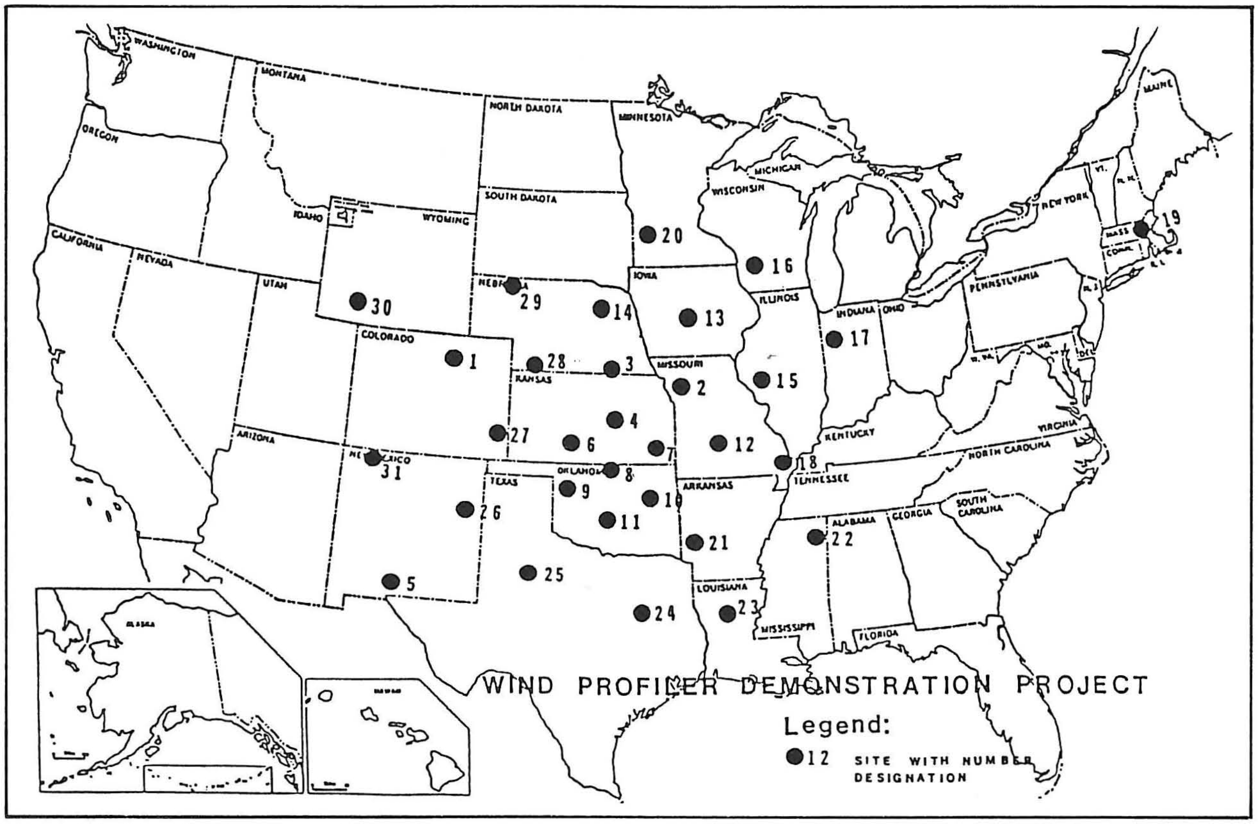

Fig. 5. Wind Profiler Demonstration Network (WPDN) Sites.

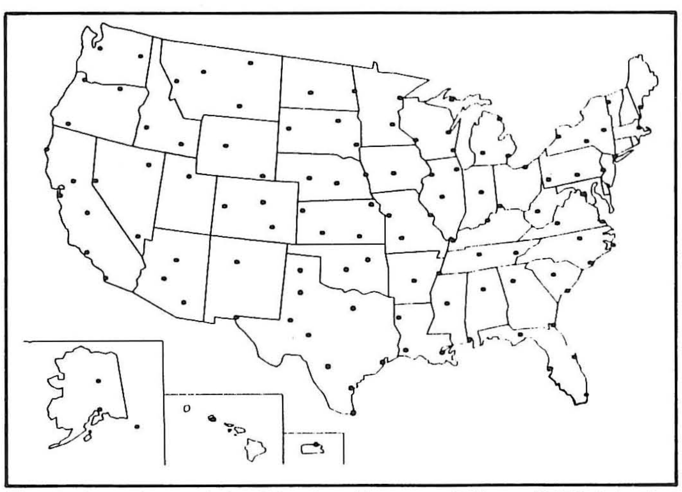

Fig. 6. Locations of the Weather Forecast Offices (WFOs) in the Modernized NWS.

The VOS program (NWS 1988) utilizes more than 1800 participating ships from 54 countries. The VOS produces over 100,000 surface synoptic observations globally each month. VOS ships report the standard meteorological parameters, and some also report oceanographic parameters such as subsurface temperature, ocean current data, salinity and oxygen content. The ship reports are sent to collection centers for ultimate transmission to NMC, using a wide range of methods ranging from voice radio transmissions and Morse code to satellite transmissions. Included in these methods are the MAREP (plain-language MArine REPorts) and SEAS (Shipboard Environmental Acquisition System) programs.

A system of NDBC moored buoys provides wind, pressure, air temperature, sea-surface temperature and wave spectra in coastal and offshore areas of the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Great Lakes. These data are transmitted hourly via GOES satellite to the NWS, rigorously quality controlled by NDBC and NMC, and disseminated in real time over AFOS. Drifting buoys also play an important role in the marine observational network, but their usefulness in the near-shore area is limited because of their tendency to run aground.

d. NMC Numerical Models

The operational global spectral models which are run at NMC produce numerical guidance used to generate forecasts of certain parameters of marine interest. The resolution of the operational numerical models is too coarse to handle these parameters in the boundary layer over the ocean surface. However, at the Ocean Products Center (OPC), which is collocated with NMC, additional physical and statistical relations are applied to the numerical model forecasts to derive ocean surface forecasts (Rao 1989). Some of the current NMC forecast parameters of interest to ocean modelers include surface wind stress, sensible and latent heat flux, radiative heat flux and a 10-meter wind forecast (which can be compared with wind observations from ships and buoys).

The NOAA ocean wave model (NOW) runs once a day with forcing provided by boundary layer winds from the operational global spectral model. In 1988, the NOAA regional ocean wave model (NROW) was implemented (Rao

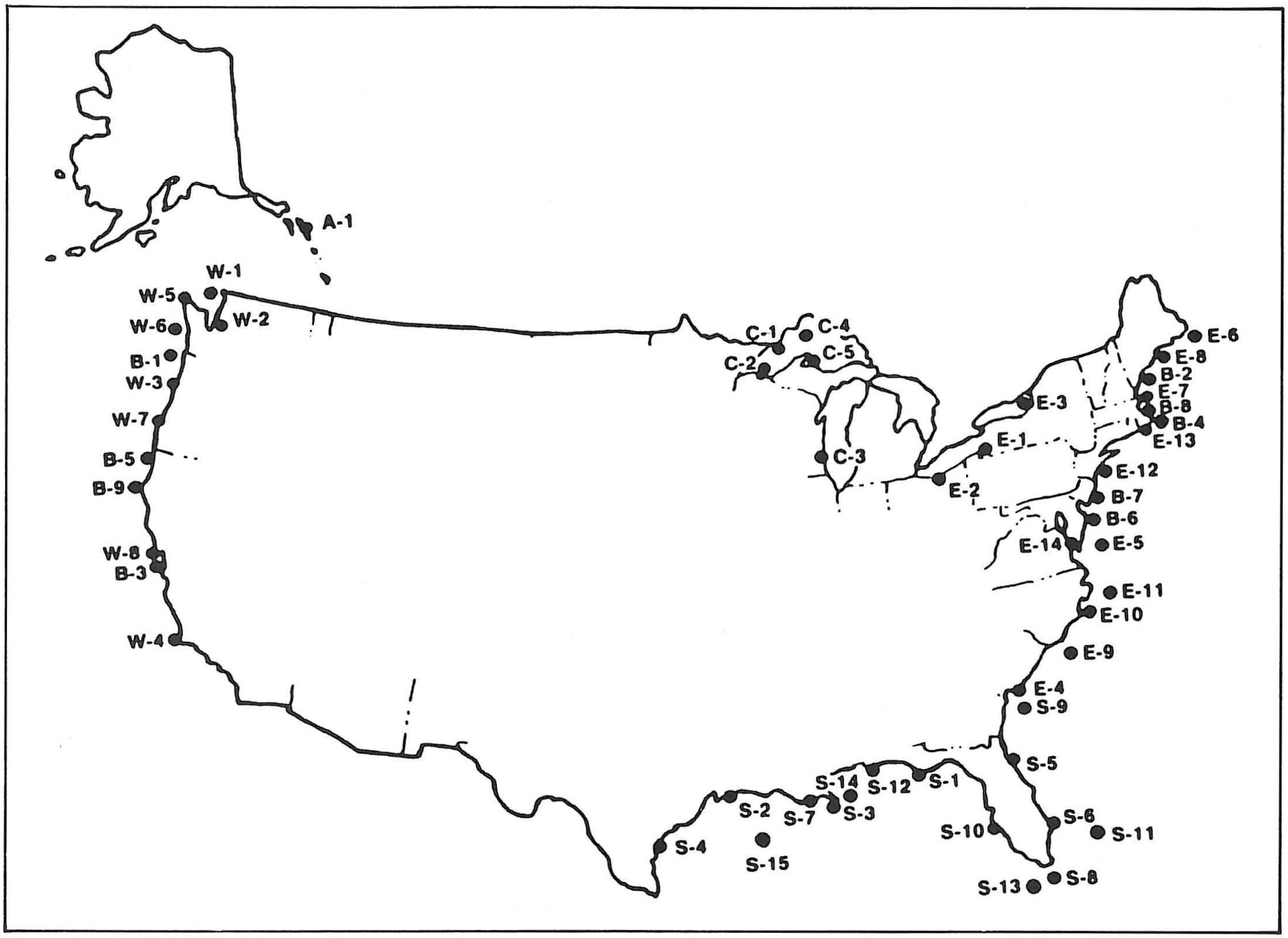

Fig. 7. C-MAN Sites in the Coastal U.S.

1989). This model is applicable to both deep and shallow waters of the Gulf of Mexico. Unlike the global model, the NROW accounts for the effects of the ocean bottom. Other regional wave models are under development or planned for the future.

Current limitations in disk storage space prevent NMC from archiving much of the boundary layer output from the models, although some archiving is being done at NMC's Climate Analysis Center in connection with some ocean modeling efforts there. It is possible that more of this output could be saved if there were sufficient demand for it by the ocean modeling community.

Future numerical systems will include a global model with more levels in the boundary layer. By 1992 experiments will have begun on coupled ocean/atmosphere prediction based upon research done at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) and elsewhere. Improvements will be made in procedures to define initial heating rates and divergence fields in areas of tropical convection. In addition, plans call for the implementation of the GFDL hurricane model on the next generation NMC computer (Bonner 1988).

NMC plans to introduce, on the next generation computers, a high resolution model for mesoscale guidance (Bonner 1989). The model would be run on demand, as often as four times per day, out to 18 or 24 hours. It could be run during periods of hurricane threats to coastal areas, anticipated major winter storms or severe weather outbreaks, etc. A horizontal resolution of 20 or 30 km is envisioned, with 30 or more vertical levels.

e. Special Programs

The NWS frequently conducts or participates in special research projects and experiments. The results of similar studies over the next few years should be useful in the development of numerical models for COPS. Many of the studies result in the development of operational techniques or programs.

One example is SLOSH (Sea, Lake and Overland Surges from Hurricanes), a diagnostic model (Jarvinen and Lawrence 1985) that computes a wind field and associated surface stresses, given specified input on a hurricane's track, size and intensity. The National Hurricane Center (NHC) has conducted numerous simulation studies for basins along the Atlantic and Gulf coasts in order to estimate maximum possible storm surges for various scenarios of hurricane strength and movement.

Another example is GUFMEX, the code name of a brief field experiment conducted in 1988 (Lewis et al. 1989). Atmospheric and oceanographic data were collected using the NOAA P-3 aircraft, ships and oil rigs, special rawinsonde and Cross-Chain LORAN (Long-Range Aid to Navigation)

Atmospheric Sounding System (CLASS) ascents, and airborne expendable bathythermograph (AXBT) measurements. The purpose of the experiment was to provide data for studies of Gulf of Mexico return flow dynamics in the late winter and early spring, when polar air of Pacific or continental origin pushes into the Gulf of Mexico and subsequently retreats northward.

Other recent experiments were GALE (Genesis of Atlantic Lows Experiment), which investigated mesoscale and air-sea interaction processes associated with cyclone development (Dirks et al. 1988), and ERICA (Experiment on Rapidly Intensifying Cyclones over the Atlantic), which focused on improving the forecasting of intense storms that develop off the U.S. and Canadian coasts in winter (NWS 1988; Hadlock and Kreitzberg 1988).

5. Summary

The development of COPS by the nation's oceanographic community will be running concurrently, in general, with the NWS Modernization and Associated Restructuring during the 1990s. The new observing systems and other technologies associated with the MAR will help provide the expanded coastal meteorological data base (including satellite-derived fields) that will be crucial to a successful COPS.

The capabilities of the new systems need to be examined carefully by the COPS developers, in order to determine the potential contribution of each system and its products to COPS. For example, how useful the WSR-88D VAD winds will prove to be (for COPS) is unknown at this time, since this radar has not been tested in a marine environment. The potential use of wind profilers is another example. Will these instruments eventually be installed at coastal locations? Can they be modified so that their primary sampling domain is the planetary boundary layer, and is it feasible to place them on buoys or offshore platforms?

The issue of how existing observing systems and programs (C-MAN, VOS, moored buoys) will evolve under MAR needs to be addressed. In fact, COPS requirements will likely be a driving force in the evolution of some of these programs. Specific recommendations (from the COPS Planning Workshop) for system requirements included, among others; (1) an enhanced (in both numbers and quality) NDBC buoy network; (2) improved resolution and accuracy of coastal ocean atmospheric observations and models; and (3) satellite observations on a continuing basis.

A fully operational COPS will likely not be realized before the year 2000. The COPS program is currently in its very early stages, and many of its specific elements, requirements, and desired capabilities are still being (or have yet to be) defined. However, this much is clear: during the middle and late 1990s, NWS (and its parent agency NOAA, which will have a leading role in COPS) will have access to tremendously greater amounts of meteorological data than have ever before been available. The oceanographic community will be able to take advantage of much of these new data in developing and implementing COPS. There will be an increasing need for coordination between the NWS and the oceanographic community during the next decade if COPS is to reach its full potential.

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