A VISION FOR THE NATIONAL WEATHER SERVICE

ROAD MAP FOR THE FUTURE

Panel on the Road Map for the Future
National Weather Service

National Weather Service Modernization Committee
Commission on Engineering and Technical Systems
National Research Council

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Cover photographs: The center image, a GOES-8 full Earth view of Hurricane Mitch (1445 UTC), October 26, 1998, was provided by the National Climatic Data Center, Satellite Resources Branch, NOAA, Asheville, North Carolina. The seven smaller images are part of a color slide collection provided by the National Center for Atmospheric Research, Boulder, Colorado. Clockwise from bottom left: simulated thunderstorm; tornado over Stapleton Airport, Denver, Colorado; simulated airflow pattern over terrain; solar plasma exploding; lightning; aurora borealis; and results of a blizzard.

PANEL ON THE ROAD MAP FOR THE FUTURE NATIONAL WEATHER SERVICE

WILLIAM E. GORDON *(chair)*, NAE, NAS, Rice University (retired), Houston, Texas
RICHARD A. ANTHES, University Corporation for Atmospheric Research, Boulder, Colorado
DAVID ATLAS, NAE, Atlas Concepts, Bethesda, Maryland
ROBERT BRAMMER, TASC, Reading, Massachusetts
KENNETH C. CRAWFORD, Oklahoma Climatological Survey, Norman
GEORGE J. GLEGHORN, NAE, TRW Space and Technology Group (retired), Rancho Palos Verdes, California
DAVID S. JOHNSON, National Research Council (retired), Annapolis, Maryland
VERONICA F. NIEVA, WESTAT, Inc., Rockville, Maryland
DOROTHY C. PERKINS, National Aeronautics and Space Administration, Greenbelt, Maryland
ROBERT J. SERAFIN, NAE, National Center for Atmospheric Research, Boulder, Colorado
PAUL L. SMITH, South Dakota School of Mines and Technology, Rapid City
ARTHUR I. ZYGIELBAUM, University of Nebraska, Lincoln

Advisors

WILLIAM D. BONNER, National Center for Atmospheric Research, Boulder Colorado
DARA ENTEKHABI, Massachusetts Institute of Technology, Cambridge
CHARLES L. HOSLER, NAE, Pennsylvania State University, University Park
ALBERT J. KAEHN, JR. U.S. Air Force (retired), Burke, Virginia

Staff

FLOYD F. HAUTH, study director
MERCEDES ILAGAN, study associate
CARTER FORD, project assistant
ROBERT KATT, consultant

NATIONAL WEATHER SERVICE MODERNIZATION COMMITTEE

RICHARD A. ANTHES *(chair)*, University Corporation for Atmospheric Research, Boulder, Colorado
WILLIAM E. GORDON *(vice chair)*, NAE, NAS, Rice University (retired), Houston, Texas
DAVID ATLAS, NAE, Atlas Concepts, Bethesda, Maryland
WILLIAM D. BONNER, National Center for Atmospheric Research, Boulder, Colorado
ROBERT BRAMMER, TASC, Reading, Massachusetts
KENNETH C. CRAWFORD, Oklahoma Climatological Survey, Norman
DARA ENTEKHABI, Massachusetts Institute of Technology, Cambridge
ALBERT J. KAEHN, JR. U.S. Air Force (retired), Burke, Virginia
VERONICA F. NIEVA, WESTAT, Inc., Rockville, Maryland
DOROTHY C. PERKINS, National Aeronautics and Space Administration, Greenbelt, Maryland
PAUL L. SMITH, South Dakota School of Mines and Technology, Rapid City
ARTHUR I. ZYGIELBAUM, University of Nebraska, Lincoln

Technical Advisors

GEORGE J. GLEGHORN, NAE, TRW Space and Technology Group (retired), Rancho Palos Verdes, California
CHARLES L. HOSLER, NAE, Pennsylvania State University, University Park
DAVID S. JOHNSON, National Research Council (retired), Annapolis, Maryland
JENANNE L. MURPHY, Hughes Information Technology Corporation, Reston, Virginia
ROBERT J. SERAFIN, NAE, National Center for Atmospheric Research, Boulder, Colorado

Staff

FLOYD F. HAUTH, study director
MERCEDES ILAGAN, study associate
CARTER FORD, project assistant
ROBERT KATT, consultant

Preface

In 1990, the National Oceanic and Atmospheric Administration (NOAA) asked the National Research Council to provide oversight and review for the modernization and restructuring of the National Weather Service (NWS). In response, the National Research Council established the National Weather Service Modernization Committee (NWSMC). This report is the last major review, under the auspices of the committee, of what has been achieved, with an additional focus on what lies ahead for the NWS, now that the modernization and restructuring is nearing completion.

In the most recent formal statement from NOAA of subjects the NWSMC should explore, the need for a long-term look at the future was expressed in these words:

> The committee's review will help ensure a continuous modernization to capitalize on the substantial investment already made in new technology, and opportunities available from emerging scientific and technological research and development efforts that will complement and enhance the modernization. Specifically the committee shall investigate the need and opportunities for continuing the modernization of the NWS beyond current plans.

This request from NOAA provided the basis for the Statement of Task for the study panel from the Governing Board of the National Research Council (see box). These instructions have guided the panel's efforts.

During the past nine years, the committee and its panels have provided advice and guidance to the NWS and NOAA on the development and implementation of each major technical system included in the modernization, as well as a host of issues related to the restructuring of NWS field offices. This report argues for the continued evolution of observational and computational technologies to improve NWS forecasts and warnings and for the NWS to seek new avenues for partnerships with others to provide a range of environmental services. The report is an optimistic view of the advances that could enable the NWS to achieve the committee's vision of weather-related information services in 2025. This optimism depends, of course, on many assumptions, the most important of which are described at the beginning of the report.

This report was developed in parallel with another National Research Council report, prepared under the Board on Atmospheric Sciences and Climate and recently released as *The Atmospheric Sciences: Entering the Twenty-First Century*. Although the two authoring groups worked independently, their reports share a vision of exciting new opportunities in atmospheric science and atmospheric information services. They agree on the main strategies for achieving the resulting benefits for the nation. The present report focuses on the NWS and suggests how the evolution and improvement of its observing and prediction capabilities may evolve

Statement of Task

The purpose of this study is to provide guidelines for the National Weather Service (NWS) to effectively exploit emerging science and technology, incorporate modernization practices into operations, and continue to improve weather forecasting and related products and services for the nation well into the twenty-first century.

The project will result in a report with findings and recommendations on opportunities for the NWS to effectively exploit and incorporate emerging science and technology into routine operations on a continuing basis. In addition to addressing technical issues, the study will suggest criteria to establish priorities for science and technology initiatives that would foster improvements in NWS operations and services.

in the context of the projected advances in science and technology.

The panel drew on the scientific and technical expertise of its members, as well as on the experience of the present and past members of the NWSMC. I thank the NWS staff for their many presentations to this panel. I thank the experts in other government agencies, universities, and industry who contributed to this study in many ways. I also wish to express the panel's appreciation to Mr. Floyd F. Hauth, study director, Mrs. Mercedes Ilagan, study associate, and Carter Ford, project assistant, for their expert organizational and logistical support. Finally, I thank consultant Robert Katt for his assistance in preparing the report.

William E. Gordon, chair
Panel on the Road Map for the Future
National Weather Service

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Raymond J. Ban, The Weather Channel, Atlanta, Georgia
John A. Dutton, Pennsylvania State University, University Park
Donald R. Johnson, University of Wisconsin, Madison
Robert C. Landis, World Meteorological Organization, Geneva, Switzerland
Fred P. Lewis, U.S. Air Force, Washington, D.C.
Ann Majchrzak, University of Southern California, Los Angeles
Clifford Mass, University of Washington, Seattle
Ronald D. McPherson, Crofton, Maryland
Joanne M. Simpson, Goddard Space Flight Center, NASA, Greenbelt, Maryland
Robert M. White, Washington Advisory Group, Washington, D.C.

While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Figures, Tables, and Boxes

FIGURES

TABLES

BOXES

Executive Summary

In this study, the committee explores ways the National Weather Service (NWS) can take advantage of continuing advances in science and technology to meet the challenges of the future. The predictions are focused on the target year 2025. Because specific predictions about the state of science and technology or the NWS more than 25 years in the future will not be entirely accurate, the goal of this report is to identify and highlight trends that are most likely to influence change. The Panel on the Road Map for the Future National Weather Service developed an optimistic vision for 2025 based on advances in science and technology. This vision is based on the seven assumptions explained in Chapter 1.

POTENTIAL BENEFITS TO THE NATION

The panel, which was established by the National Research Council to conduct this study for the National Oceanic and Atmospheric Administration (NOAA), predicts that in 2025 vastly improved weather information products and services will be substantially more useful to society than they are today. The formal NWS modernization and restructuring, now being completed, has provided the foundation for the NWS to lead the way in realizing enormous benefits to the nation. Advances in scientific understanding will enable advances in forecasting techniques. New observational, data assimilation, and modeling systems will be based on scientific advances and technological innovations. The resulting improvements in the accuracy of forecasts will foster markets for weather and related environmental information and will create new opportunities for providers of commercial products and services. To meet the challenges that lie ahead, the NWS must evolve in response to a rapidly changing user and technological environment.

Recommendation 1. The National Oceanic and Atmospheric Administration and the National Weather Service should more aggressively support and capitalize on advances in science and technology to increase the value of weather and related environmental information to society.

ENABLING SCIENCE AND TECHNOLOGIES

Based on improved scientific understanding, advances in observational and computational technologies will greatly improve the spatial and temporal density, accuracy, and timeliness of weather and climate data and information. Measurements of surface and upper air conditions will be made by automated surface observing networks, by airborne observing systems, by advanced Doppler radar processing technology, and by satellite-based observing systems. New methods of data assimilation will enable higher resolution numerical weather prediction models to represent accurately the physical processes responsible for weather and weather-related phenomena (atmospheric physics and hydrologic processes). New techniques will improve local forecasts by combining data from diverse observing systems taken at different times with results from large-scale modeling and local climate information (hybrid forecasting). Information about the accuracy of forecasts and measures of uncertainty in predictions will be more sophisticated, yet more understandable to users. Descriptions of the key physical processes and conditions at grid points over an entire basin (distributed modeling) will replace older methods of modeling the effects of precipitation and snow melt on streams and rivers.

Ongoing national and international scientific research and technology development will provide the foundation for these improvements, which will lead to a proliferation of user-oriented services and products. To realize these enormous opportunities, the NWS and NOAA must prepare to upgrade current observing systems and regain and maintain state-of-the-art computing facilities. They will have to keep abreast of research in the scientific community by actively supporting and participating in the U.S. Weather Research Program and other partnerships.

Recommendation 2. The National Weather Service should be an active partner and participant in national and international research enterprises in weather, hydrology, climate, and environmental sciences.

The NWS must adopt an evolutionary approach to upgrading its operational systems with new technology rather than relying on episodic overhauls. An evolutionary approach will avoid obsolescence and organizational trauma, minimize risks, and enable more timely implementation of improved tools. The rapid development, testing, and implementation of new algorithms and techniques will require sound science and proficient engineering.

Recommendation 3. The National Weather Service should commit to and plan for ongoing and timely incorporation of scientific and technical advances in the operational weather observation, analysis, and prediction system. To implement its commitment, the National Weather Service should take the following steps:

- Develop technologies, in cooperation with universities and the public and private sectors, that enhance systems for observing weather phenomena and for assimilating and analyzing resulting data.
- Evaluate, on a quantitative basis, alternative technologies and approaches for the development, testing, and deployment of a cost-effective system of synergistic observing instruments and platforms, incorporating the principle that integrated measurements taken by multiple sources using diverse techniques can provide a better estimate of a physical quantity than any one instrument alone.
- Test and evaluate new forecasting concepts and systems expeditiously, through rapid prototyping at the appropriate centers or selected forecast offices.
- Maintain a research staff of sufficient size and expertise at the national centers to develop new forecast techniques and products that further their broad national missions.
- Work with the National Oceanic and Atmospheric Administration to strengthen National Weather Service interactions with the National Environmental Satellite, Data, and Information Service and the Environmental Research Laboratories, ensuring that their combined activities are coherent, systematic, and mutually supportive.
- Work with the academic community on a continuous basis to improve numerical weather prediction models.
- Maintain a strong scientific capability at the field offices to conduct application-oriented research and development at the local level (for example, through the science and operations officers and development and operations hydrologists).
- Provide appropriate computing capabilities at field offices to ensure that new technologies can be tested and applied.

The future success of the NWS and the quality of its service to the nation will be determined in large measure by the capability of the computer resources made available to it. Improvements in forecasts will depend on the assimilation of timely data from a broad array of observing systems into computer-based models of the atmosphere, which are vital to modern weather and climate prediction. Running increasingly accurate models at higher resolutions quickly enough to produce useful forecasts will require increased computational power. Parsimony in purchasing NWS computer power is therefore a false economy that deprives the nation of valuable benefits.

Recommendation 4. Congress and the administration should provide the resources needed by the National Weather Service to regain and maintain the state-of-the-art supercomputing capability required to support the advanced analysis and modeling systems that are fundamental to the nation's weather and climate forecast systems.

MERGING WEATHER INFORMATION SERVICES INTO ENVIRONMENTAL INFORMATION SERVICES

The panel expects that continuing progress in weather forecasting, enabled by major changes in meteorology, hydrology, oceanography, and associated technologies, will combine with the continuing transformation of the United States to an information-oriented society to make weather and related environmental data increasingly valuable to a wide range of users. Consequently, the number and variety of participants in the national (and global) network that provides environmental information will increase dramatically. Consumers will use the information to meet their commercial needs and personal interests by integrating traditional weather data (probably in common gridded formats) with other data on the environment and on specific economic sectors. The increasing number and range of nonfederal public, private, and mixed public-private providers of these data and value-added applications will both respond to and create opportunities for new information services and products.

The NWS's role is expected to evolve as provider networks grow. First, the panel expects that the NWS will retain its lead role in issuing public forecasts and severe weather warnings. It must, therefore, constantly improve its dissemination system by exploiting new ways that information providers communicate with end users. Second, the NWS will increasingly provide observational data and gridded forecast products to other information providers, including the traditional disseminators of NWS products (emergency preparedness agencies and broadcast media), as well as public-sector and commercial producers of

specialized products and services. Third, partnering with other governmental entities (federal, state, or local) as well as private entities will be essential for fulfilling the fundamental mission of the NWS.

Recommendation 5. The National Weather Service should collaborate with a variety of partner-providers to integrate weather and related information into comprehensive environmental information services.

ORGANIZATIONAL ISSUES

Enlightened strategic planning is critical to enable the NWS to interact with and serve its constituents. To meet the changes in user needs and efficiently upgrade its technology and operations, the NWS will require stable long-term funding that is adequate to implement long-range plans based on validated requirements. Irregular or inadequate support limits the quality and extent of services and denies potential benefits to the entire user community.

Recommendation 6. The National Weather Service should perform strategic long-range planning for orderly development of the infrastructure and technology that support the services for its constituents. Congress, the Office of Management and Budget, the U.S. Department of Commerce, and the National Oceanic and Atmospheric Administration should provide stable and adequate funding to the National Weather Service consistent with its needs and plans.

A rapidly evolving user community, advancing technology, and changing relationships among members of the weather community will require evolution in the organizational structure of NOAA and in the relationships among its components, including NWS, the National Environmental Satellite, Data, and Information Service, and the Office of Oceanic and Atmospheric Research.

Recommendation 7. The National Weather Service should routinely examine and anticipate the needs of primary customers and ultimate users. In the context of changing requirements, the National Oceanic and Atmospheric Administration should periodically adapt its organizational structure and operating processes to foster effective relationships among the National Weather Service, the National Environmental Satellite, Data, and Information Service, and the Office of Oceanic and Atmospheric Research.

Because the atmosphere and oceans transcend national boundaries, realizing the national weather and climate predictive capabilities envisioned in this report will require a free and open exchange of higher-quality and higher-resolution global observations. Creating the requisite global database will require improved cooperation among the major data-gathering nations.

Recommendation 8. The National Weather Service should maintain and strengthen its leadership role in seeking international cooperation for the free and open exchange of weather and climate data for the benefit of users in all nations.

The role of the forecaster will change as NWS personnel who have meteorological or hydrologic expertise spend less time preparing routine forecasts and more time interacting with customers and refining, extending, and validating the models and other tools of automated prediction. Interactions with other participants in the network that provides environmental information (the provider network) will be essential for incorporating environmental observational and forecast data into application-specific decision-support aids and for improving the dissemination of public forecasts and severe weather warnings. The heavy investment in technology for NWS operations will require a technical support staff that is expert in the operation, maintenance, and upgrading of this technology.

Recommendation 9. The National Weather Service should provide for the ongoing professional development of a knowledgeable, flexible workforce through continuing education and training, taking advantage of appropriate university resources.

Given the primacy of its role in the current provider network, the NWS could be well positioned to lead, and not merely react to, changes in the national and international systems for providing environmental information services. Both primary customers of NWS products and services (in the provider network) and ultimate consumers of the information should understand and appreciate the role of the NWS in sustaining and expanding the provider network.

Recommendation 10. The National Weather Service should participate with other public institutions, professional societies, and the private sector in educating the general public and specialized users about the causes and consequences of weather-related environmental phenomena; the utility and limitations of environmental observations, forecasts, and warnings; and the roles of the National Weather Service and its partners in providing this information.

At the end of Chapter 5, the panel lists criteria NWS can use in selecting science and technology initiatives. The list includes both general criteria, applicable to all areas, and criteria specific to observing systems, computer facilities, new NWS products, and education and training.