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ORGANIZATION OF NMC WASHINGTON

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OVERVIEW

The National Meteorological Center (NMC) plays a unique and essential role in the public weather services of the United States, one of technically guiding the forecast process from a national level. For instance, the process that ends with a weathercast on commercial television or radio began at NMC a few hours beforehand. Activities in several disparate functional areas support the processing tasks at NMC, and the training and experience of personnel are correspondingly diverse. The three major areas of specialization are

- meteorologists and meteorological technicians,
- research scientists, and
- computer scientists and operators, and electronic technicians.

These specialties provide fairly clean lines along which to erect divisional walls, with a good balance between internal homogeneity and size of primary organizational unit. With some important exceptions, NMC is organized this way.

MISSION

To help forecasters in the field do their job--that is the primary reason for the existence of the National Meteorological Center (NMC). This primary mission dates back to about 1942 when its forerunner, the National Weather Analysis Center, was established to do in one location and with one staff what previously had been done in many locations by many more forecasters and meteorological technicians. Higher quality and consistency were thus achieved by distributing to field forecasters one set of analyses and prognostic charts prepared by specialists in the task. These were important reasons for centralizing--to achieve economies and at the same time produce somewhat higher quality products. Those same reasons exist today, but so profoundly that a truly modern weather service canot exist without access to centrally produced guidance materials. Decentralization today would mean either the prohibitive expense of many very large computers, or inferior products produced with inadequate computer facilities.

The public forecast process begins at NMC with runs of several numerical analysis and prediction models on the NOAA central computers. Statistical and manual interpretations and modifications of the numerical analyses and predictions are also made. As products are completed they are transmitted via AFOS*, facsimile, and teletype not only to all field offices of the National Weather Service (NWS), but also to many other users--private, commercial, academic, and governmental--both military and civilian. Figure 1 schematically shows lines of flow of such information.

Within the NWS, NMC provides guidance materials to 52 Weather Service Forecast Offices (WSFOs). The four other centers shown in Figure 1, which deal with tropical or severe local storms, also use NMC's basic guidance in preparing their predictions and guidance materials. In turn, each WSFO

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*Automation of Field Operations and Services, a computerized system installed for communication and display of data and products, and for local forecast applications.

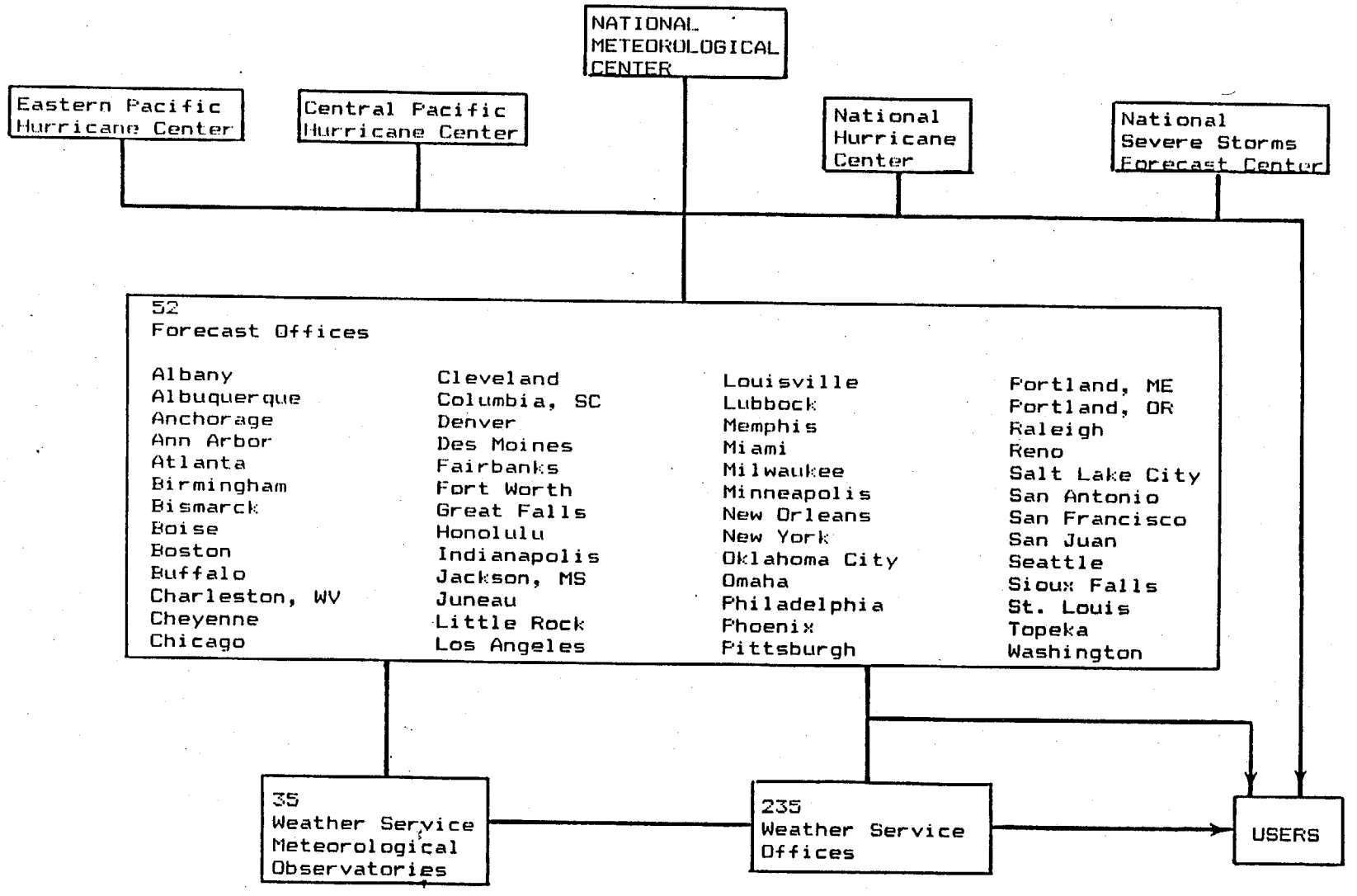

Figure 1. Structure of the Forecast Organization.

provides on the average about five Weather Service Offices (WSOs) with forecasts local to their areas. The WSOs and WSFOs provide direct service to the general public by continuous broadcasts on dedicated FM radio channels; and in cooperation with local telephone companies, with recorded messages. The most important link to the general public, however, is through commercial news media--television, radio and newspapers.

A public service cannot--and should not--restrain its flow of information within closed channels, and indeed, NMC along with all of the other NWS Centers and Offices, provides information directly to many users. These include aviation interests, wire press services, industrial meteorologists, and other governmental agencies such as the Bureau of Reclamation and the Federal Aviation Administration (FAA).

NMC has acquired a number of other functions since its establishment in 1961. First, NMC's role in telecommunications has expanded. Second, physical oceanography is now included in NMC's mission. Third, in response to the World Climate Program NWS added to NMC's functions that of short-term climate fluctuations. Fourth, NMC provides information directly to many end users. An example is the transmission of aviation products to the FAA for control of air traffic, and to airlines and other companies for preparation of flight plans.

MAJOR FUNCTIONS

Telecommunications

Communications functions are divided between NMC and two organizations within the NWS Office of Technical Services--the Communications Division and the AFOS Operations Division. Because of the increasing number and complexity of new communications requirements, consideration is being given to consolidation of these functions into a single NWS office.

In 1961 NMC's functions in telecommunications were to receive information required for its operations, and to transmit its products via facsimile and teletype. Recently this function has expanded to include entry of data and products on the NWS AFOS system. With the institution of World Weather Watch, NMC became a regional hub for exchange of data in the Global Telecommunications System (GTS). Because of its national and international importance, the measures taken to backup this function are most extensive. For example, emergency power is available for equipment used in exchanges of international data, which is not true for many other NMC activities. On the main GTS circuit, NMC links Bracknell on the east with Tokyo on the west. Numerous other lines enable NMC to fulfill the U.S. commitments to collect and transmit regional data, and give NMC access to all data regularly exchanged internationally.

Telecommunications at NMC are fully automated. NMC owns and operates three mainframe computers (IBM 4341), many minicomputers, and various switching and storage devices. On-line disk systems peripheral to the 4341s have the capability of storing 6.5 gigabytes, of which 1.8 gigabytes are reserved for operating and other systems. There is, by the way, a 5 km microwave link between the building housing both NMC's mainframe computers and NOAA's IBM 360/195s and CYBER 205, and the building housing almost all of NMC's activities. In 1972 most of NMC was moved from its old location to accommodate expansion of computer-conditioned space to make way for the IBM 360/195s. In order to continue its operations and research without loss of efficiency, the microwave link was set up. The terminals on the link are diverse--CRTs to receive and display alphanumerics and graphics; digitizers automatically to read, digitize, and transmit information read from manually drawn charts; facsimile-type devices to receive digital information and produce very high quality charts; line printers large and small; and card readers and punchers. Technically, the 5 km could as well be 5000 km or more--perhaps an important point for others as well as us.

All of these automatic communications links, plus those that are direct to users, adds up to a very large communications center handling very large volumes of data in many different formats.

Guidance

Figure 2 is a schematic of the guidance and forecast process. The start of the process must await the acquisition of observations in sufficient numbers and with sufficient global three-dimensional coverage. The lapse between nominal time of observation and start of the guidance process is a matter of judgment on the balance between accuracy and timeliness of delivery of the products. The observations come from many sources:

upper air observations from radiosondes,
soundings and cloud-tracked winds from satellites,
winds and temperatures from commercial aircraft,
surface observations from ground stations and ships at sea, and
sea surface temperatures from satellites and ships at sea.

At the core of the guidance system are numerical weather analyses and predictions made on state-of-the-art computers. From the numerical predictions made with dynamical atmospheric models, statistical guidance products are prepared. These are for specific locations and are made from statistical relationships derived from a vast body of historical data. Examples of predicted variables are maximum and minimum temperatures at major cities, ceiling and visibility at large airports, and probability of rain and snow. Although NMC has the responsibility for the daily production of statistical guidance, the systems are developed in the Techniques Development Laboratory of the Systems Development Office, NWS. Their accuracy is limited to a degree by their developmental data base, but mainly by the accuracy of the dynamical predictions from which they are produced.

Subjective guidance is also prepared from dynamical model output. From the standpoint of product count, subjective guidance represents only a minor part of the whole guidance package--about 5% of the total. But it remains an essential part, especially in the area of weather itself--heavy precipitation and the demarcation between rain and snow. This is precisely where dynamical models are weakest.

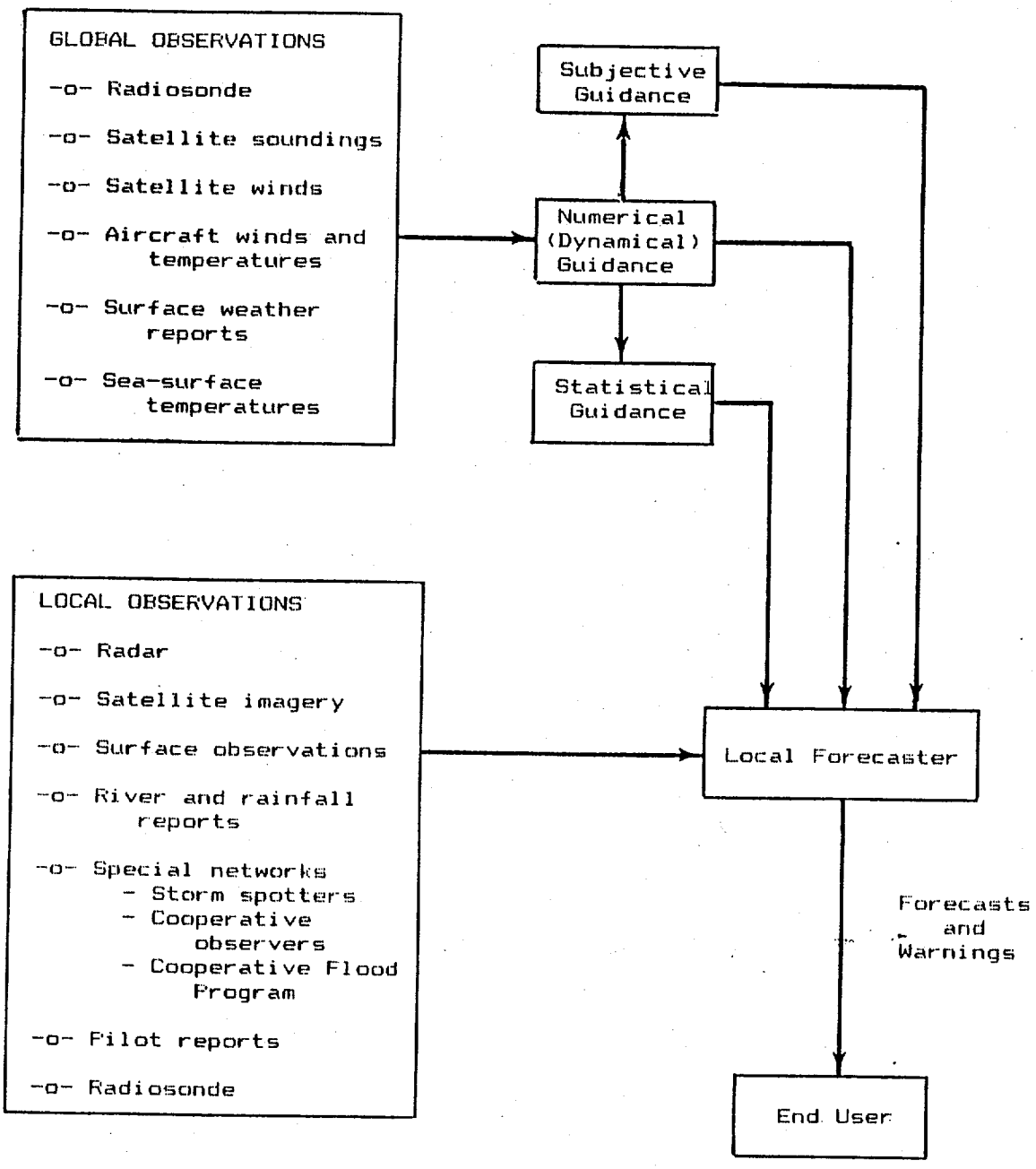

Figure 2. Weather guidance and forecast process.

The local forecaster has at his disposal, not only the three types of central guidance, but also many observations from his local area. The local observations not only supplement the central guidance with areal detail, but are also more timely by several hours than those incorporated by central guidance. They are most helpful in ranges less than 18 hours, but provide little if any useful information beyond 36 hours. For the very short ranges and very small scales, local observations are crucial. A dramatic example is the report of an approaching tornado made by storm spotters stationed around a city or town. Approach of a flash flood on a stream or small river is another. The responsibility for these kinds of short-fuse warnings is shared by the WSFOs and WSOs.

The evolution of the atmosphere from one state to another is controlled by natural laws. These laws are well known and are embodied in classical hydrodynamics and thermodynamics as a set of partial differential equations in the four dimensions of space and time. The laws imply that prediction of the atmosphere is an initial-value problem. That is, if we knew perfectly the state of the atmosphere everywhere in all its detail right now, then we could in principle predict its future states perfectly for all time to come. In practice, of course, we can't do this. There are several fundamental reasons.

We have no way of solving the full set of differential equations. Instead we solve approximate equations, either finite difference, truncated spectral, or a mixture of the two. Our knowledge of the state of the atmosphere at any given moment is imperfect. Even the well-known natural laws are not complete. We know a great deal indeed about the governing laws, but not everything. We are, and ever shall be, approaching perfect predictions, but will never arrive there. With more and more powerful computers, our approximate equations will contain less and less error. With more accurate and more dense observations, our knowledge of the initial state will continually improve. And research will uncover new knowledge about how the atmosphere and its bounding systems work, and how to use it.

ORGANIZATION

The Director of NMC reports directly to the Director of the National Weather Service. This is an important feature of the NWS structure. It provides appropriate visibility to the functions and needs of the organizational element that drives the whole forecast process. More accurate weather forecsts depend on progress in NMC's core activity--numerical weather prediction--more than on anything else. Therefore, not only does NMC drive the whole forecast process, but also NMC activities are the principal source of improvements in the public forecast service. Another factor behind its position in the NWS organization is that it is assigned a large portion of the total NWS resources.

The operation of the very large supercomputers is not within NMC's nor NWS's purview. Automated central guidance products are produced on the Central Computer Facility operated and maintained by the NOAA Office of Information Management Systems. The National Weather Service and the National Environmental Satellite, Data, and Information Service of NOAA use over 90% of the resources of the facility. The facility is equipped with several main frame computers, including a newly acquired CYBER 205 manufactured by Control Data Corporation.

Another feature of organizational structure which differs from some other centers is the large research and development staff within NMC. Managers of operational activities, and the manager of the research program all report directly to the Director of NMC, which provides a short administrative link between the two kinds of activities. We believe that this facilitates innovation into the operations.

The organization of the U.S. NMC is summarized in Figure 3. The total staff of the Center presently numbers 289, and never strays far from 300. The staff is split approximately 80/20 between operations and research. Although NMC has reorganized internally every few years in response to changing demands on it and in response to scientific and technological advances, the organizational structure at the top has withstood the test of time--30 years. The structure at the top of NMC generally reflects organization along lines of the talents and specialties of individual people and the methodologies they employ in their work. Thus, operational meteorologists and meteorological technicians dominate in the Forecast Division, computer programmers in the Automation Division, and meteorological researchers in the Development Division. In practice, this turns out to be not very different from organizing along functional lines, and it simplifies somewhat the management functions.

The Climate Anaysis Center (CAC) is a center within a center, and does not follow this organizational principle. The Climate Analysis Center may be regarded as a reincarnation in much broader form of the old Extended Forecast Division. Some of the functions had been retained in the Long Range Prediction Group. The new Center was organized at division level in NMC in response to new national and international interest in documentation and prediction of short-term climate fluctuations.

This Center in the future could well be organizationally removed from NMC with the two Centers becoming siblings. However--dictated by current state-of-the-art--its size, functions, and demands for its products are too small for it to fare well on its own. At the same time its functions are more closely related to the other NMC functions than to those of any other organization within NWS and NOAA. It therefore makes sense for it to be an NMC division for now.

The Forecast Division prepares all manual products in the short, extended, and medium ranges. These are currently defined, respectively, as less than 3 days, 3 to 5 days, and 6 to 10 days. Manual products include modifications to automated analyses and forecasts, quantitative precipitation forecasts, and special products for aviation. Under the new world-wide area forecast system planned by the International Civil Aviation Organization (ICAO) with the help of WMO, NMC is one of two ICAO World Area Forecast Centers, and also is one of many ICAO Regional Area Forecast Centers. The Division fulfills the U.S. commitment, under ICAO agreements, to supply significant weather charts for international flights. The Division does real-time round-the-clock monitoring of the computer operation. Division staff are usually the first to detect problems arising with the daily computer operation, and have the responsibility to raise the alert and coordinate corrections. The senior Division person on duty carries the responsibility for all of the operations of the Center for the 3/4 of the time that the week-day daytime staff are absent. The Division Chief makes recommendations to the Director concerning content and format of Center products.

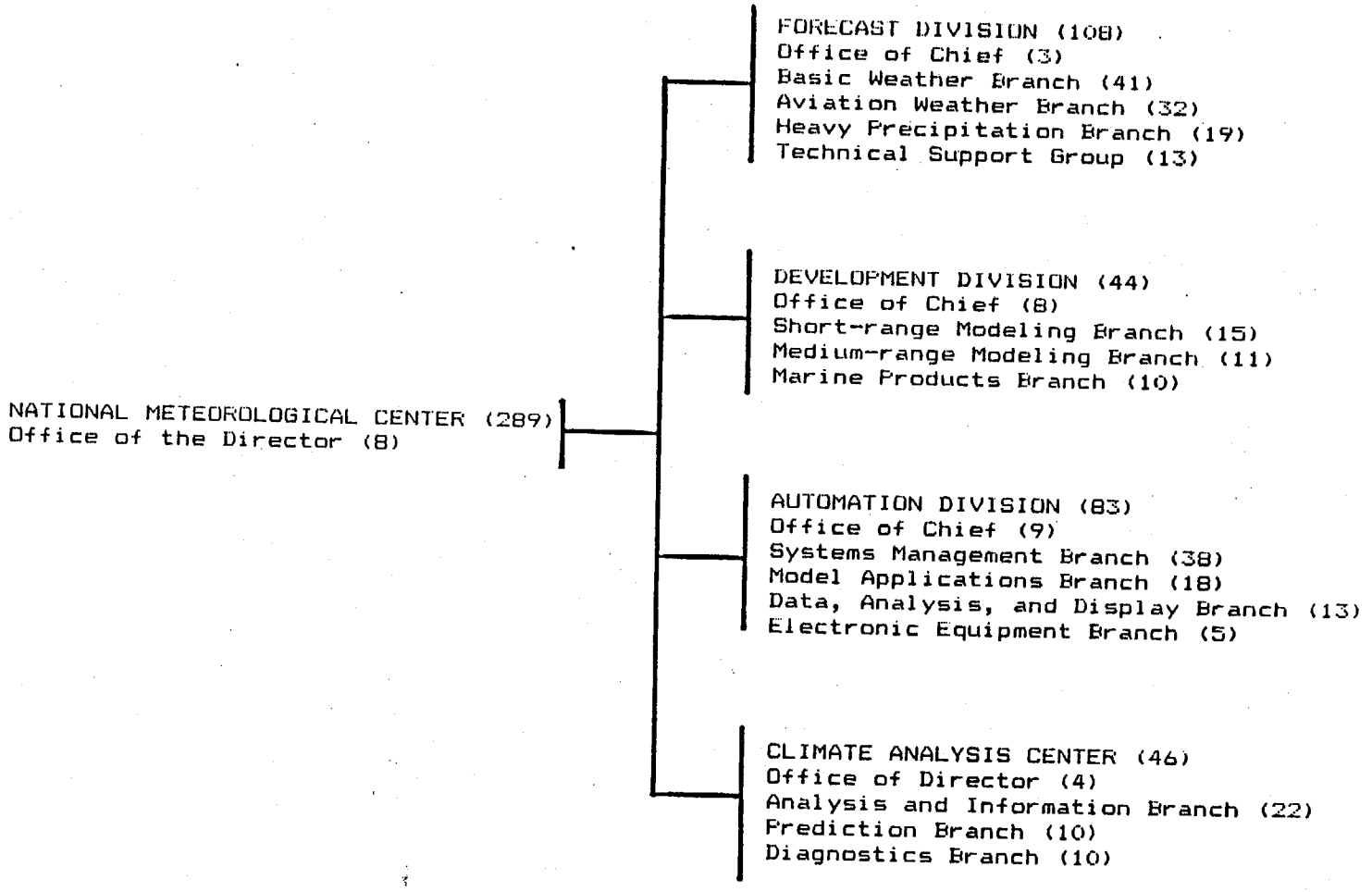

Figure 3. Organization of the National Meteorological Center.

Automation Division develops systems software not provided by computer vendors. Division staff maintain operational computer programs and systems, convert software to newly acquired computers, and optimize existing programs. They develop automated graphics techniques, and design and develop graphics systems. The automated communications function is placed in Automation Division because it is technically similar to many of the Division's other functions. Division staff operate all of NMC's computers. They perform maintenance of mini-computers, terminal devices, and communications interfaces. The Division Chief makes recommendations to the Director concerning hardware and software configurations.

Development Division staff perform virtually all research and development done in the Center in numerical weather analysis and prediction, including data assimilation and initialization techniques. The Division Chief advises the Director on the state-of-the-art in numerical weather analysis and prediction, and on operational feasibility of new methods developed inhouse and elsewhere. The Marine Products Branch is currently within Development Division. The Branch conducts research and development in physical oceanography, and develops new operational products. As its activities expand, the Branch may be elevated to Division level.

The Climate Analysis Center issues outlooks for as long a period as is possible, now judged to be 90 days. It maintains awareness of short-term climate fluctuations, and acquires and maintains the world-wide data base needed for this function. The Center disseminates short-term climate information to users, and conducts applied resarch and development aimed at improving its products. The CAC Director advises the NMC Director on the state-of-the-art in his area and makes recommendations for operational innovations.

DEPENDENCE ON THE WORLD METEOROLOGICAL ORGANIZATION

In the international arena the principal need common to all meteorological centers is quick access to global data. Particularly important to us is the work of the Commission for Basic Services in fostering international cooperation and agreements which permit such access. Other functions, such as those in research and development, standardization, and training, are important, even essential, but the sine qua nons for meteorological centers in today's world are the Global Observing System and the Global Telecommunications System.