

part 4

THE FUTURE ROLES OF PEOPLE AND MACHINES IN WEATHER FORECASTING*

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1. INTRODUCTION

It is an interesting exercise to project ourselves ahead to the year 2000 and see how weather forecasters may be interacting with machines. In this paper we shall attempt such a 22-year forecast.

One way to predict the future is to first look backwards over a similar period of time and see what changes have actually occurred. Then one can project at least a similar degree of change for the same period into the future. We are now in 1978 and projecting ahead to 2000. If we move backward an equal 22 years, 1956 would be our reference point for comparison with the present.

2. THE FORECASTING SYSTEM IN 1956 - EMPHASIS ON PEOPLE

In what kind of environment did the forecaster operate in 1956? To begin with, the forecaster had a lot fewer reports to contend with because there were no satellites or network radars such as the WSR-57's. In fact, very little radar coverage was available in 1956.

Only a few large computers existed, and they were very slow. The barotropic was the only major numerical weather prediction (NWP) model in operational use, and it had many limitations. Thus, the 1956 forecaster received little help from numerical forecast guidance.

Similarly, automated statistical forecasting techniques had not been perfected in 1956. The forecaster had to rely to a great extent on a manual system of plotting data, analyzing maps, and making prognostic charts.

It is true that facsimile was available to the field forecaster in 1956, but most if its contents were prepared by humans in weather centrals. In fact, the National Meteorological Center (NMC) as we know it today was not founded until 1958. In short, the machine was barely integrated into the traditional human forecasting system back in 1956.

3. FORECASTING IN 1978 - THE HUMAN/MACHINE MIX

The 22 years from 1956 to the present have seen technology make a tremendous impact on operational meteorology. Machines now play an important role in every aspect of this field. Let us briefly review the current status of automation in weather observing, forecasting, and communication.

3.1 Observing

Recent years have seen the development of a

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number of kinds of automatic surface observing stations. Just this year a very complex automated observing system, called AV-AWOS (Aviation Automated Weather Observing System), was successfully demonstrated in a joint four-month NWS/FAA test at Patrick Henry Field, Newport News, Virginia (Figure 1). AV-AWOS is designed to serve small to medium-sized airports staffed by FAA observers. Additional sensors and processing can be added to employ AV-AWOS at larger airports staffed by NWS observers.

A remarkable feature of AV-AWOS is its ability to produce a computer-generated voice giving the weather observation. During the test period, the AV-AWOS observation from Patrick Henry Field was transmitted at certain hours in place of the manual observations taken by FAA personnel. The system performed well throughout the test.

Other automatic observing stations now in use include the families of stations called AMOS (Automatic Meteorological Observing Station), RAMOS (Remote Automatic Meteorological Observing Station), AUTOB (Automatic Observing) station, AHOS (Automatic Hydrologic Observing Station), and LNB (Large Navigational Buoys). A cheaper version of AV/AWOS is being developed for use at over 900 airports staffed by FAA which have no observations at all at the present time.

Unfortunately, the increasing deployment of automatic observing stations has not offset a long-term decrease in the number of surface observations and ocean station vessels. In some special cases, such as remote sites, the automatic stations have freed-up observing personnel to perform more useful work elsewhere in the system.

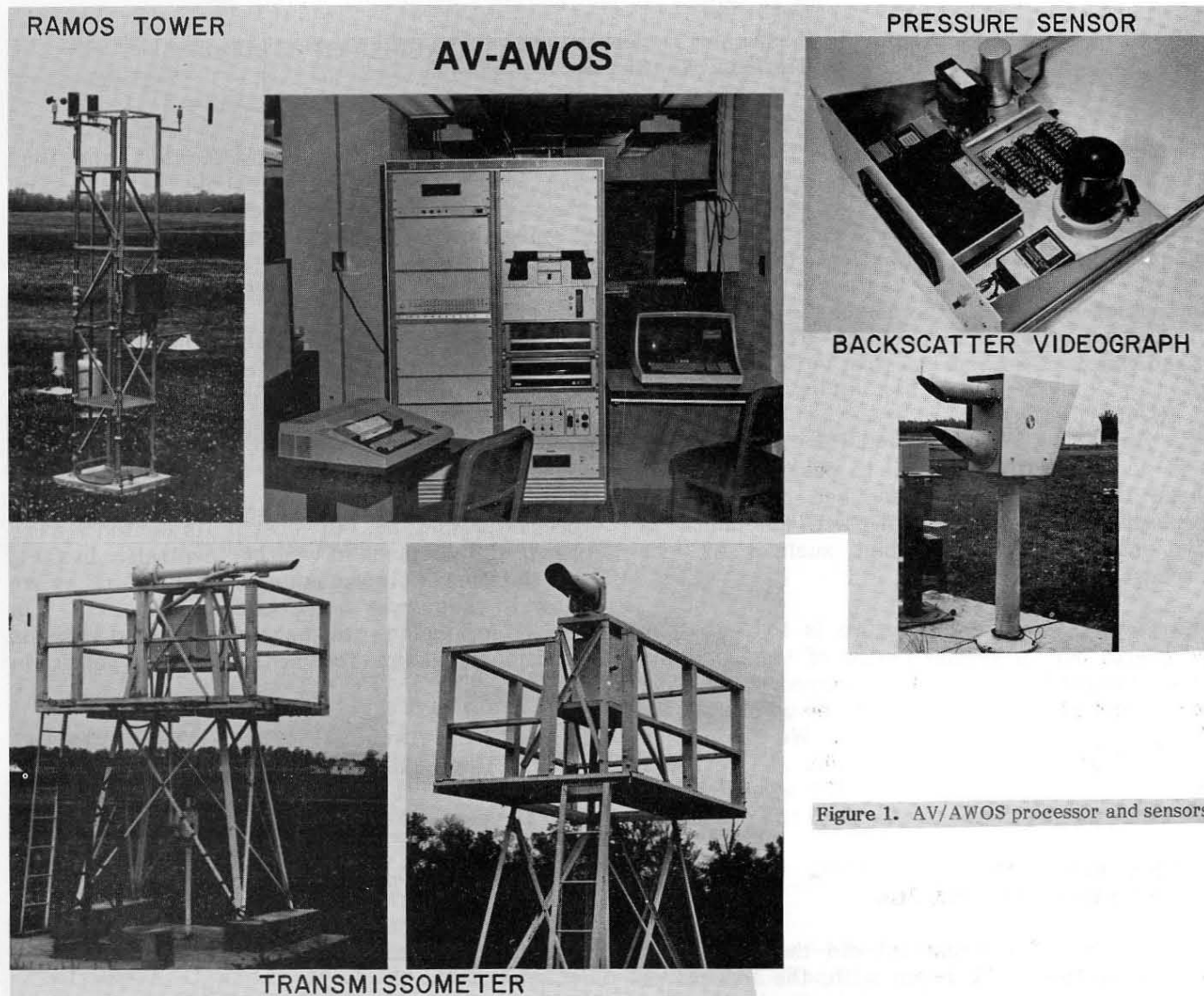


Figure 1. AV/AWOS processor and sensors.

Today's meteorologist is, however, inundated with radar observations from the national network consisting of WSR-57's, WSR-74S's, a few military radars, and a profusion of local use radars (WSR-74C's). Similarly, today's forecaster has a wealth of satellite data to interpret, none of which was available 20 years ago. Thus, the forecaster of 1978 actually has a serious problem in trying to assimilate all of the data now available.

3.2 Forecasting

The computer has come of age in the last 20 years so that the meteorologist now has all kinds of new forecast guidance. Take the matter of numerical forecast models in operational use by the National Weather Service. NMC now runs the following models operationally:

- o Barotropic
- o LFM II
- o 7-Layer Hemispheric PE
- o Movable Fine Mesh (on demand)
- o 9-Layer Global
- o 3-Layer Global (3 times per week)

Naturally, dozens of forecast products are produced by all of these models and distributed to field forecasters.

A second big area where forecasting with computers has made great strides is in the field of statistical prediction. The model output statistics (MOS) technique for producing automated guidance from the output of numerical models was first implemented on a nationwide basis in 1972. NWS now produces regularly MOS forecasts of such weather parameters as surface temperature,

probability of precipitation occurrence and amount, type of precipitation, probability of heavy snow, ceiling and visibility, cloud amount, thunderstorms, severe local storms, and surface winds. A sample matrix of MOS forecasts is shown in Figure 2.

The objective forecasts listed in Figure 2 provide the basis for the completely automated computer-worded forecast shown at the bottom of this figure. Structured to resemble the official public forecasts prepared by humans, these automated forecasts cover three periods of interest such as today, tonight, and tomorrow. The expected conditions of weather, cloudiness, temperature, and wind are included, and probability of precipitation is appended at the end of each message. These products are currently produced once a day and made available to some NWS field offices which have cathode ray tubes.

Clearly, the operational forecaster of 1978 has an abundance of computer-prepared guidance to assist in making the forecasts. The meteorologist is actually finding it difficult to improve upon the machine guidance beyond the first 12 hours of the forecast period.

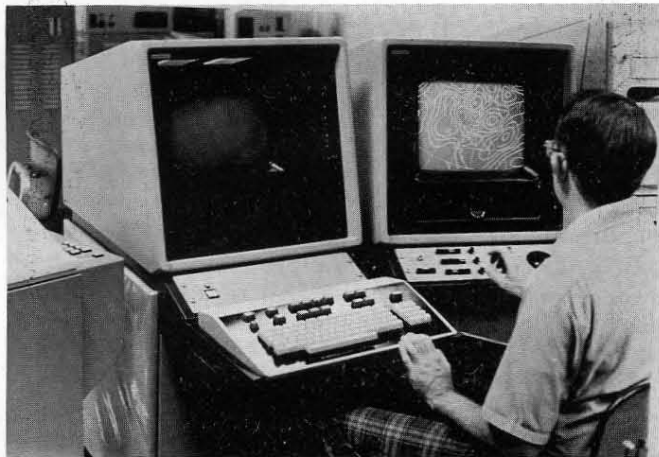
3.3 Communications

A revolution is under way at present to convert the National Weather Service (NWS) from conventional facsimile and teletypewriter systems to minicomputers, soft displays, and digital facsimile.

The cornerstone for the future is the Automation of Field Operations and Services (AFOS) System

TDL AUTOMATED FORECASTS (USING EARLY GUIDANCE)									
FRIDAY 16 JUNE 1978									
WASHINGTON, DC		VALID TIME							
ELEMENT	UNITS	12Z	18Z	00Z	06Z	12Z	18Z	00Z	
		(--TODAY--) (--TONIGHT--) (--TOMORROW--)							
TEMP M/M	DEG F	80 66 84							
TEMP	DEG F	63	66	74	78	75	70	68	
POP(12)	PERCENT	11 20 25							
POP(6)	PERCENT	7 7 10 17 15 21							
POF	PERCENT	0 0 0 0 0 0 0							
R SHR(L)	PERCENT	49 51 76							
DRZL(L)	PERCENT	11 20 0							
RAIN(L)	PERCENT	40 30 25							
TSTM	PERCENT	0 1 6							
QPF	CATEGORY	1 1 1							
CLOUDS	CATEGORY	1	4	4	2	4	4	3	
WIND D/S	DEG MPH	1403	1504	1606	1703	1606	1810	1610	
CIG	CATEGORY	6	6	6	6				
VIS	CATEGORY	6	6	6	6				
WASHINGTON, DC		SUNNY THIS MORNING, BECOMING OVERCAST BY MIDDAY. LITTLE CHANGE IN TEMPERATURE, HIGH NEAR 80. LIGHT AND VARIABLE WINDS. TONIGHT--MOSTLY CLOUDY WITH A SLIGHT CHANCE OF SHOWERS, LOW IN THE MID 60S. LIGHT AND VARIABLE WINDS. SATURDAY--CLOUDY WITH A SLIGHT CHANCE OF SHOWERS. HIGH IN THE MID 80S. PROBABILITY OF RAIN 10 PERCENT TODAY, 20 PERCENT TONIGHT, AND 20 PERCENT TOMORROW.							

Figure 2. A model output statistics (MOS) automated forecast matrix and the resultant computer-worded forecast.



(Figure 3). AFOS is a major new fully integrated and automated system of data collection, handling, and dissemination in support of field operations and services. With this system, NWS plans to have automated support at nearly all its field offices and national centers by 1981.

AFOS is based on the use of modern mini-computers and cathode ray tubes (CRT's: TV-type displays) plus supporting modules such as hard

Figure 3. AFOS alphanumeric and graphics display console.

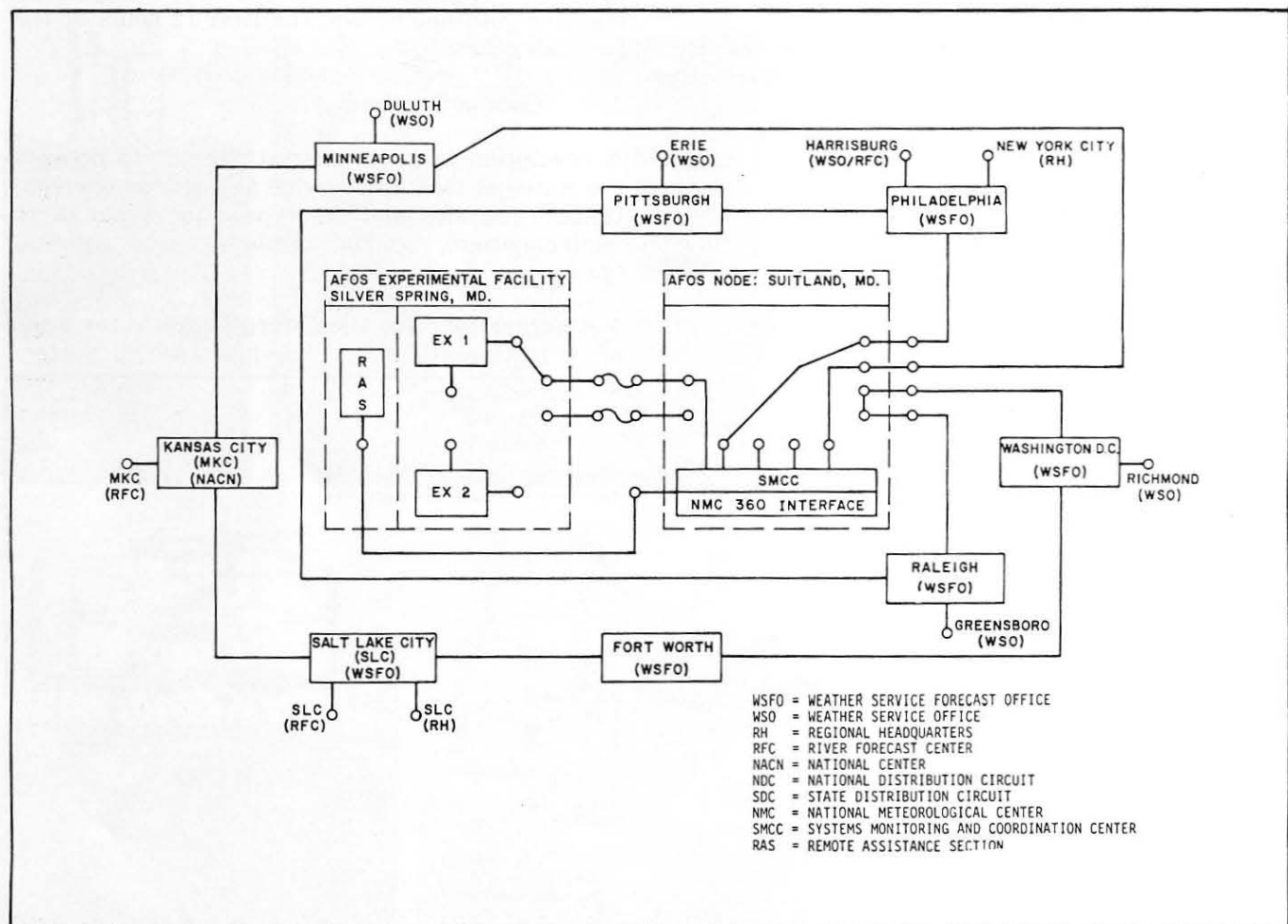


Figure 4. Single Field Loop Test Configuration for an NDC in the early stages of AFOS implementation. By switching, two separate NDC's can be established (the outer loop and the inner loop). SDC's are the connecting spurs between WSFO's and WSO's.

copy devices. With this AFOS equipment, both alphanumeric and graphic weather data and forecasts can be displayed on the CRT's. Paper copies can be produced as necessary with the hardcopy device.

The key to the rapid communications with AFOS is the National Distribution Circuit (NDC) which connects all Weather Service Forecast Offices (WSFO's) and national centers in a closed loop. There are also State Distribution Circuits (SDC's) connecting smaller NWS offices with WSFO's in a star-like configuration. Figure 4 shows a planned test arrangement of an interim NDC connecting the first stations receiving AFOS equipment.

Another new communications system now being implemented is the digital facsimile. With this improved technique, graphic products can be sent to users in about one third the time required with conventional facsimile circuits.

Why are we automating so many subsystems and implementing other technological improvements in NWS? The basic reason is tight personnel ceilings. Because of these restrictions on personnel, NWS must learn to do everything faster and more efficiently if it is to provide new services to our expanding population. In particular, warnings, need to be disseminated as quickly as possible to the people affected, and this requires the use of modern, high-speed communications.

4. THE FORECASTER IN THE YEAR 2000

What can be foreseen as the role of the forecaster 22 years into the future? To begin with, we know that AFOS, and similar systems in the military services, will be in widespread use. With such systems, forecasters will be freed from the drudgery of such present routine tasks as tearing and posting paper and using old-fashioned typewriters to compose messages. The meteorologist will be able to prepare messages and send them directly to users with the push of a button.

In addition, forecasters will have new aids to help monitor and forecast the weather. Computer-worded public, zone, state, and specialized service forecasts will be available in the mini-

computer systems, so that the forecaster need only insert modifications where he/she takes exception to the computer's forecast. Another type of supporting program will be computer routines that automatically compare the latest official forecasts with current observations, warn the forecaster when the forecast needs to be amended, and even suggest what the new forecast should be. Such a program for aviation terminal weather is already near the implementation stage

in NWS as an AFOS application.

Between now and the year 2000 we can expect the NWS AFOS system to undergo some rather dramatic advances. Many of these, such as animation, interactive graphics, faster telecommunications, conversion to color video displays, etc. will come as the result of better and less expensive technology. Others, particularly in the area of forecast applications, will come as a result of on-going Government and university research efforts.

Perhaps the outstanding example of these efforts is the work being done at the University of Wisconsin-Madison with the Man-Computer Interactive Data Access System (McIDAS). With this system, significant advances have been made in the processing and (video graphics) display of both satellite and conventional meteorological data. Many of these advances will ultimately find their way into the AFOS system in the form of computer programs which produce satellite-derived upper wind fields, streamline analyses, divergence and vorticity fields, pressure and temperature contours, mesoscale analyses, etc.

Synoptic scale, numerical forecast models will undoubtedly be improved by the year 2000 to the point where the human will not have to touch the products beyond the first 12 hours of the forecast. Statistical forecasts based on these numerical predictions will also be generally accepted for projections longer than 12 hours. Mesoscale forecast models will be operational by the year 2000, too, but they probably will still be sufficiently inaccurate that the human can improve on them.

With respect to data acquisition, it is likely that automatic stations and computers will have taken over virtually all human roles in observing except for a general monitoring function. Meteorological data will move directly from radars, satellites, and automatic surface stations to the AFOS system.

Much of the new data explosion will come from future implementation of the Prototype Regional Observing and Forecasting Service (PROFS) or something similar. Under this program, dense mesoscale surface and upper air observing networks will be established around hundreds of major cities. New, cost-effective remote sensing

systems would be relied upon to provide the upper air observations.

To improve synoptic scale upper air observing capabilities, NWS is presently completing development of an Automatic Radiotheodolite (ART). The objective is to refurbish and reconfigure old upper air equipment, incorporating automation wherever possible. By 2000, soundings should be completely automated, perhaps by means of

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remote sensors from satellite and surface platforms.

There will be an explosion of radar data, particularly as the Doppler radar concept is implemented across the nation. With Doppler radar, the early detection rate for tornadoes and severe local storms is bound to improve markedly.

Help is on the way for the radar data explosion. An equipment system called RADAP (RADAR DATA Processor) will be procured and installed by NWS in the early 1980's. RADAP will provide the first operational automated radar data processing, communications, and display.

The forecaster of the future thus need not lose heart about being overwhelmed by the data explosion. Computers will be efficient enough to process all of these new data and to feed suitable outputs to the forecaster in digestible forms. Advances in the field of microprocessing, coupled with the relatively low prices of such equipment, will allow the application of automated assistance in many new areas. The present SPAD (Sensor Processing and Display) system, which takes input from meteorological sensors and produces a digital display, is an early example.

Dissemination is yet another area where a lot of assistance is on the way for the human. The NWS now relies heavily on the NOAA Weather Radio (NWR) which is being installed at over 300 stations across the land. Human forecasters must now laboriously prepare and frequently update messages. However, by the year 2000, digital-to-voice techniques will surely be perfected so that computers will produce and automatically update routine radio forecasts. The role of the human will be to monitor and intervene in rare cases and to update for the short range (0-12 hr) forecast period.

Hopefully, it may be possible to develop a cable TV dissemination system similar to the NOAA Weather Radio. In addition, we have recently demonstrated the feasibility of another method for presenting weather information on television. With this second method, minicomputers can be interfaced by means of a telephone and a small electronic box to a person's home TV. Thus, weather observations and forecasts can be presented directly on a home television screen.

The forecaster of 2000 will thus be relieved of data collection tasks, routine forecast preparation work, the need to produce operational forecasts beyond the first 12 hours, and the drudgery of routine dissemination tasks.

What, then, will be left as professional work for the field meteorologist? The authors see five major areas where the forecaster can be usefully employed, as follows:

4.1 Short Range Forecasting and Nowcasting

Even in the year 2000, the human will be valuable for the forecasting of local weather events in the 0 to 12 hours time frame. Mesoscale models will not be accurate enough to catch all local weather changes.

It is this nowcasting and short range forecasting that is of greatest interest to the general public even at the present time. It is also the period in which accurate and timely warnings can save human life. In this area, the meteorologist will still have an important role to fill.

4.2 Specialized Forecasts For Specific User Groups

Since AFOS will have "freed-up" a lot of time for the operational meteorologist, there will be opportunities to spend more time interfacing with major user groups and helping solve their forecast problems. For example, NWS forecasters could work more closely with other government agencies such as the FAA, the Forest Service, and the Army Corps of Engineers to solve problems on a daily basis.

4.3 Community Relations Work

More operational meteorologists could be involved in the process of educating the local communities on what NWS products and services are available and what actions can be taken in advance of severe weather to mitigate its effects. In fact, given the modern communications capability of AFOS and the probable nationwide availability of NOAA Weather Radio (NWR), NWS may be able to provide its warning services with fewer operational forecast offices in the year 2000.

If a number of the offices now involved in the round-the-clock effort of forecast production can be removed from the operational mode, then personnel can be freed for a community education type of function. It is conceivable that many NWS offices could then be converted to 1- to 3-person stations of primarily day workers who would spend most of their time interfacing with the community. Since station complements could be smaller in many cases than with today's system,

NWS might even be able to increase the total number of weather stations serving the nation. We would then have more offices and be able to provide increased services, and yet have fewer people involved in the daily production loop.

4.4 Development of Local Forecast Procedures

At the larger forecast offices there should, hopefully, be opportunities for forecasters to develop local forecast programs to run on their mini-

computers. NWS won't have this capability initially in AFOS, but such an ability should be provided as soon as possible to offer another creative area of professional development for meteorologists. Besides, the persons nearest to the local forecast problems usually have the greatest interest in developing more accurate forecasts for their area.

4.5 Systems Monitoring Functions

Monitoring of the automated observing systems, numerical forecast products, and all aspects of the AFOS system will be an important function. Quality control must be maintained to insure that no deterioration occurs in NWS forecasts. The human will still be the ultimate backup and quality controller in the foreseeable future.

5. CONCLUSION

Our nation can look forward to more accurate and timely forecasts and warnings in the future.

People in the forecast production system will see, in many cases, a vast change in the specific duties of their jobs. Skills such as computer programming, engineering, electronics, and public relations will be increasingly in demand. On the other hand, there will be less need for some of today's skills in the work force. In particular, the forecaster aide, observer, and communicator positions will no longer be required.

Despite greatly increased automation in weather observing, forecasting, communication, and dissemination by the year 2000, the human will still have important functions to fulfill in several different areas of meteorological service.

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REFERENCES

Although specific references have not been given in the text, the following papers contain interesting material relevant to the future of weather systems:

Brown, J. A., Jr., 1976: Modelling and the man-machine mix at the National Meteorological Center, Washington. WMO Symposium on the Interpretation of Broad-Scale NWS Products for Local Forecasting Purposes, Warsaw, 11-16 Oct. 1976, WMO No. 450, Geneva, Switzerland, pp. 151-158.

Cahir, J. J. and J. M. Norman, 1977: Analysis of frontal weather by forecaster interaction. Report for the period Sept. 1976 - 14 Sept. 1977, NOAA NWS Contract No. T-35406, Dept. of Meteorology, Pennsylvania State University, University Park, Pa., 63 pp.

Clodman, J., 1976: The development of a computerized forecast system. WMO Symposium on the Interpretation of Broad-Scale NWS Products for Local Forecasting Purposes, Warsaw, 11-16 Oct. 1976, WMO No. 450, Geneva, Switzerland, pp. 159-169.

Fritsch, J. M., and C. W. Kreitzberg, 1978: Workshop on local weather forecast techniques - 1980 and beyond. Drexel University, Philadelphia, Pa., 10-1 March 1977. *Bull. Amer. Meteor. Soc.*, 58, 293-296.

Glahn, H. R., 1976: Progress in automation of public weather forecasting. *Mon. Wea. Rev.*, 104, 1505-1512.

Klein, W. H., 1969: The computer's role in weather forecasting. *Weatherwise*, 22, pp. 195-201.

Klein, W. H., 1976: The AFOS program and future forecast applications. *Mon. Wea. Rev.*, 104, 1494-1504.

Kreitzberg, C. W., 1977: Meteorological services for hazardous weather. Unpublished manuscript, 22 pp.

Pielke, R. A., 1977: An overview of recent work in weather forecasting and suggestions for future work. *Bull. Amer. Meteor. Soc.*, 58, 506-519.

Space Science and Engineering Center, 1978: Innovative video applications in meteorology (IVAM) August 1974 - March 1978. Final Report, NOAA Contract 5-35156, University of Wisconsin, Madison, Wis.

Staff, Systems Development Office, 1977: Programs and accomplishments, fiscal year 1977. National Weather Service, NOAA, U.S. Department of Commerce, Silver Spring, Md., 50 pp.

University of Wisconsin, 1977: An introduction to McIDAS. Interactive Video Displays for Atmospheric Studies, Proceedings of a Workshop at the University of Wisconsin-Madison, 14-16 June 1977.

Zink, H. D. and W. Plummer, 1976: Automated voice readout of computer generated weather reports. Space Communications Group, Applied Physics Laboratory, Johns Hopkins University, Laurel, Md., 74 pp.