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Numerical Weather Prediction Activities

National Meteorological Center
First Half 1970

U.S.
DEPARTMENT
OF
COMMERCE

Environmental
Science
Services
Administration

Weather
Bureau

SILVER SPRING
MARYLAND

July 1970

~~151-405~~

UNITED STATES DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

NUMERICAL WEATHER PREDICTION ACTIVITIES
NATIONAL METEOROLOGICAL CENTER

FIRST HALF OF 1970

CONTENTS

I. REVISIONS IN OPERATIONAL PROGRAM

A. Primitive Equation Prognostic (PEP) Boundary Layer Temperature Initialization

On March 10, 1970, a modified method of determining the boundary layer temperatures hydrostatically, from the thickness of the layer when the PE grid point terrain is above the height of the 850 mb surface, was implemented. This modification eliminated the problem of the initial boundary temperature being too warm. (See Item III.B.)

B. Quantitative Precipitation Selection Modification

On March 19, 1970, several changes were introduced into the PEP model so as to induce more precipitable water. This was necessary because the laminated moisture concept that was implemented on October 30, 1969, (see Semi-Annual Report Second Half 1969, Item I.A.) tended to underforecast precipitation. The new procedures are described in Item III.C.

On June 1, 1970, a further modification to enhance a potential source of precipitable water in the PEP model was accomplished by bypassing the smoothing procedures of the initial relative humidity analysis. (See Item III.C.)

C. Air Pollution Potential (APP) Program

The APP program became operational on February 13, 1970, utilizing forecast information from the 00Z PE model, plus wind, temperature and stability data from radiosonde observations and urban low level soundings. Stagnation indices are derived in order to determine areas of large scale stagnation and air pollution potential. Details about the forecast model and output package are documented in ESSA Weather Bureau Technical Memorandum No. 47. (See also Item III.Q.)

D. Revision of Extended Forecast System

A new daily extended forecast guidance system, based on 12Z initial data, was implemented on February 9, 1970. This system includes: daily sea-level pressure, 500 mb heights and anomalies, 1000/500 mb thicknesses and anomalies, maximum-minimum temperature anomalies, and precipitation probabilities; observed and forecast 5-day mean sea-level and 700 mb charts; and statistical objective 5-day mean temperature and precipitation anomalies. (See Item IV.D.1.)

II. DATA AUTOMATION DIVISION

A. Statistical Techniques and Analysis Branch

1. Satellite Infrared Radiation Spectrometer (SIRS) Data

a. During the period from December 1969 to March 1970, a special analysis forecast cycle was run in order to evaluate the usefulness of SIRS data. During this special cycle, the analysis program was constrained so as not to reject or alter SIRS data, not make any use of conventional data from ships, or use any monitoring (bogus) data. In addition, the analyses were run without manual intervention so that the computer program could delete other conventional data if necessary. The special cycle was kept separately from the operational cycle and the 12-hour forecasts for first guesses were obtained from the 3-level model. Twice weekly a primitive equation (PE) forecast was made in order to compare with the operational analysis-forecast cycle. Output from these forecasts was collected and verified. For the same cases, the operational forecast output was also collected and verified.

Verifications were made for each of a group of 70 regular observing stations (including 12 OSV's). Forecast errors were determined by checked RAWINSONDE winds and temperatures at six isobaric levels. Verifications were also made at initial time and every 12 hours out to 48 hours. Results were obtained and stored for each of the 70 stations, and summaries were prepared showing statistics of wind and temperature errors for several subsets of the 70 stations. In addition, a persistence forecast was also verified and summarized in the same manner as the operational and test forecasts. The verification data will appear in a report by E. B. Fawcett of the Analysis and Forecast Division (A&FD).

b. A test has been made using forecast height changes for updating off-time reports to synoptic time. The purpose was to determine a feasible method for updating SIRS reports. Radiosonde 500 mb heights were updated, for periods from five to twelve hours, with the appropriate forecast height tendencies to be valid at the time of the subsequent height reports at the same locations. Comparisons were made of the updated and verifying heights. Verifying heights, which had failed the hydrostatic check, were not included. The 3-hour forecast height changes from the PE model and the 3-level model were used for the updates.

The results of the updating of a complete set of data for 12Z April 10, 1970, through 00Z April 11, 1970, revealed that the forecast height changes from both models produced an improvement over persistence of 10 meters (RMS). For short-period updates (5, 6, or 7 hours) the PE model height changes showed an improvement over persistence of three meters (RMS). The 3-level model showed an improvement of seven meters.

These results are only for a small sample. Additional testing will be done later on a larger data sample. If the results for the 500 mb level are favorable, similar testing will be made for other levels, e.g. 850 and 200 mb levels.

c. The advective method of correcting off-time SIRS reports (see Semi-Annual Report for Second Half 1969, Item II. A. 1. b.) was completed and implemented for the 12Z final analyses beginning May 19, 1970. Only SIRS data between 06Z and 18Z are utilized and a very slight difference in the analyses is noted from this updating procedure.

The surface (sea level pressure and surface temperature) analysis program has been run successfully on the NMC octagonal grid. Attention was given to methods of detecting and deleting erroneous reports. Some experiments have been performed in which the relative amounts of weight given to the sea level pressure, compared to the surface winds, have been varied. The upper-air analysis program is being modified so as to treat the 300 mb level as a key level as opposed to the 500 mb level. This will utilize more observational data (because of aircraft wind reports) than is available at the 500 mb level. An investigation is underway to determine whether the use of the weighting function, $W = (R^2 - d^2)/(R^2 + d^2)$, significantly alters the analysis if defined in earth-space versus grid-space (on the map surface). The latter is the conventional procedure that was used previously.

2. Objective Analysis

a. An upper-air processor program which prepares the data for the analysis programs has been reprogrammed for the CDC 6600 computer. These data are put into a packed format in the disk file and can be used by programs which need the mandatory level information. This program also used forecast wind shears to extrapolate aircraft wind reports from flight levels to isobaric levels. A similar processor for the surface data is also being written.

b. Work is continuing on converting the northern hemisphere surface and upper-air analyses programs for processing on the CDC 6600 computer. These programs use the data prepared by the pre-analysis processors mentioned in a. above. Preliminary results indicate that height variations at the grid points are well above meteorological noise level for the continental United States at the 500 mb level.

c. Operational programs were altered to make use of the tropical region temperature analyses for the international flight planning bulletins. Prior to these changes, climatological temperature values were issued.

d. The tropical analysis program has been modified to accept observational data in the format mentioned in a. above.

3. Verification of wind and temperature forecasts

Monitoring of the monthly temperature forecast errors of the PE model has revealed a persistent warm bias for the 300, 250, and 200 mb levels. This bias is especially noticeable at initial time and is

apparently due to the method of transformation from potential temperatures in the sigma-layers of the model to temperatures at constant pressure levels. This transformation does not affect the model itself, but does affect its evaluation because constant pressure temperatures are verified. By applying the transformation method to radiosonde soundings, it has been determined that the higher levels (near 250 mb) are assigned temperatures which are warmer than the radiosonde values. Alternative procedures for obtaining the constant pressure temperatures are being tested.

4. Pre-GARP Basic Data Set

All of the NMC backlog from the November 1969 collection (see Semi-Annual Report Second Half 1969, Item III.A.6) was processed. This involved processing 20 days of surface data; running approximately 18 tropical analyses which were missed during November; stacking the data and analysis files for shipment to the National Climatic Center, Asheville, N.C.; and putting the NESC ATS-1 data into the proper format for inclusion by Asheville in the master file.

For the June collection, several changes in procedures have been implemented. The surface and upper-air missing station lists have been improved and provisions for providing summaries of the data collections have been designed and programmed. The missing station list program, which was used for the November GARP program, has proved to be very useful in supplying information about the data receipt for our operational runs. The information has been summarized for United States stations by the Quality Control Specialist of NMC. Because of the wide interest in and the value of such information, additional effort will be made to improve and expand these programs.

5. National Hurricane Center Support Programs

a. In support of the National Hurricane Center (NHC), 12 test cases were conducted for the 1969 hurricane season to aid in a study of determining the feasibility of employing Dr. Sanders' fine-mesh analysis and forecast method for hurricane tracking. In conjunction with this study, the NMC fine-mesh analysis program was modified to remove the influence of the hurricane during the analysis and then re-entering the hurricane into the wind field after the analysis was completed. These two methods of forecasting hurricane movement are to be evaluated by NHC.

b. Dr. Sanders' analysis and forecast programs have been modified to run operationally via the "200 User Terminal" at NHC. The bogus data card input required for the Sanders analysis program have been converted to a format more compatible with the operations unit at NHC.

B. Programming Branch

1. Program Conversion

The description of NMC data files for CDC 6600 operations is being formulated. The data within the files will be in the forms

described in NMC Office Notes 28 and 29. Working data files will be stored in permanent files provided under the Scope operating system. Random access of fields will be provided through NMC subroutines W3FK26-W3FK30 using Mass Storage I/O in FORTRAN.

The following subroutines were made available from the 6600 System Library to programmers using FORTRAN Extended:

W3AI00	Pack field data
W3AI01	Unpack field data (data are in the format described in NMC Office Note 28)
W3AI02	Unpack upper-air reports
W3AI03	Pack upper air reports
W3AI04	Unpack surface reports (data are in the format described in NMC Office Note 29)
W3FB00	Compute I,J coordinates from Latitude, Longitude
W3FB01	Compute Latitude, Longitude from I,J coordinates
W3FC00	Compute wind speed and direction from U,V components of wind
W3FC01	Compute U,V components of wind from wind speed and direction
W3FC02	Compute wind speed and direction from U,V components of wind (grid oriented)
W3FC03	Compute U,V components of wind from wind speed and direction (grid oriented)
W3FI00	Reverse indexer
W3FI01	Single mesh field indexer
W3FI02	Double mesh field indexer

Subroutines on which work was done include: Rotate and interpolate a data field, Title program for GRDPRT titles (W3FP00), connect a field packed by W3AI00 to the old packed format used on the IBM 7094.

2. The programming needed to encode SIRS data for teletype transmission was completed. Domestic transmission of SIRS-B data will start with the beginning of the next reporting period.

3. Updating of the ADP upper-air dictionary continued. Information sources were WMO Publication No. 9, Vol. A and the ETAC

dictionary.

4. Preliminary work was done on the Howcroft Fine Mesh Forecast (see Item III.K.), in preparation for running on a CDC 6600 with Extended Core Storage. The model will use a 63 x 63 square mesh grid.

5. Work continued on the ESSA-FAA sponsored Clear Air Turbulence (CAT) project. (See Semi-Annual Report Second Half 1969, Item II.B.3.b.).

6. Additional programming on the IBM 360 Surface ADP program was done to improve the June GARP data set.

7. Programming assistance to the Development Division continued. Work included:

a. Testing the Phillips Two-Layer Pressure Change Model for northern hemisphere forecasts.

b. Work on an extension of the limited-area fine-mesh model to a multi-layer baroclinic model.

c. Work on an implicit integration method.

d. Assistance with Robert-Shuman-Gerrity instability tests on a PE barotropic model.

8. Tropical forecast charts at 500, 300, and 200 millibars on a 1:20,000,000 Mercator section for aviation purposes were transmitted to Miami beginning May 7, 1970. This is the first operational application of the package of subroutines being developed by DAD for graphics on the CDC 6600. In this application, the CDC 6600 program takes the given grid point values of stream functions, winds, and temperatures, and forms the complete map at 1:40,000,000 scale in packed digital scan-line format. The map includes contours, contour-labels, shading, plotted point-values, titling, and a background map.

An IBM 360 program is used to extract a section and change the scale to 1:20,000,000 and transmit, through the Digital-Facsimile Interface (DFI), to Miami.

9. A general purpose output display package was developed using the CDC 6600 graphics package to output analysis and forecast charts for the standard octagonal input array. Currently, the 1:50 M scale and 1:25 M scale (Howcroft fine-mesh) backgrounds are used to produce charts with (a) contours, (b) center and numeric values, (c) shading, and (d) title information. Eventually, contour labels and data plotting will also be available. Output to Varian or DFI is possible.

10. The framework for a display package that could be used as a "Utility" program was developed. This package would allow a programmer to supply a single input array format and data type scaling constants (i.e., heights, temperature, isotachs, etc.) to produce a Varian output chart. However, more work must be done in this package to allow all of the various input data types possible.

C. Information Processing Branch

The following are operational changes on IBM System 360 #1:

1. The 2400 baud biosynchronous data-link between NMC and Toronto became operational with the start of a 3-day operational test on February 24, 1970. At the conclusion of the test, it was decided to continue rather than revert to the NMC Montreal data-link.

2. Coincident with the above change was the start of transmissions from NMC to ADIS (Service A) on a polled basis. These transmissions include the FA, FT, SA and FL bulletins from Toronto, and NMC prepared FD's, AS and FS. For a time, it was necessary for Toronto and the border stations to continue to back up the FT's into ADIS. These stations were finally deleted in early April, and by mid-April the local ADIS box was disconnected.

3. The AFTN (Aeronautical Fixed Telecom Network) switch with Kansas City also became operational on February 24, 1970, starting out with two 100 wpm transmit lines from NMC to Kansas City, and later expanding to receive from Kansas City on three 100 wpm lines (one of which, in mid-April, replaced the line connected to New York relay center.

4. Several other low speed lines were introduced during this period. These included two 66 wpm lines to Brazilia (full duplex), two 100 wpm lines to Anchorage (full duplex), and a low speed 60 wpm transit line to Cuba. Circuit #8275 became half duplex in mid-March and circuit #8276 in early June (both adding transmission capability).

5. Numerous and important directory changes accompanied all of these line additions and changes.

6. Several changes took place in the Aviation Digital Forecasts, namely:

a. Automatic retrieval for either Marsden square blocks or entire files became effective in early January with Pan-American and Speas and Associates, currently the only operational users.

b. Air Canada was added to the polling list in mid-January 1970.

c. The long-awaited transmission of these forecasts in packed decimal format (2 numeric digits instead of 1 per transmitted

character) commenced April 1, 1970. Changes in some of the headings, extensions of some forecast areas, and the addition of entirely new areas (Asia, India and South Africa) also became effective. Despite the additions and expansions, the packed decimal format decreased the total time of transmission from 55 to 45 minutes.

7. Other changes that were accomplished during this period included the following:

a. "Daisy-Chain" in mid-March. This allowed us to decrease the basic processing cycle for incoming data from 5 to about 1.5 minutes.

b. A program to print out diagnostic information when machine checks occur to aid the IBM Engineers in diagnosing problems.

c. The first use of the extra 65 K of 360-40 core storage.

d. A program update to quickly point out when one or more lines are down.

e. A program improvement to allow more capability in displaying or altering core locations.

f. A code to enable us to retrieve and retransmit bulletins to ADIS.

g. The RGTR code was updated to store surface hourly reports on the swing-disk (common disk to more than one system).

h. The CRT program changed to delete unusable Canadian FT stations from entering ADIS.

i. The expansion of the ADIS code to handle scans, and permit the transmission of amended, delayed and corrected FT's to Toronto.

j. The dropping of the special ADIS dump code for TDL (RALF).

k. The distribution of new bulletins (generated on system 360 #2) such as FTxx1 KWBC and SMCN 7-13 KWBC.

The following are operational changes on IBM System 360 #2:

1. NMC assumed the responsibility for preparing tropical area wind and temperature forecasts on June 1, 1970, (disseminated thru System #1):

FDCA5-6 KWBC replaced portions of FACA KMIA
FDCA1-4 KWBC replaced portions of FUCA KMIA

FDUS4-5 KWBC replaced bulletins FUU55-6 KWBC
FDNT1 KWBC replaced FUNT2 KMIA

2. Various decoders and formatters were rewritten or modified to process data from the swing-disk for the June 1 GARP project.

3. With the demise of RALF on System #1, surface hourly data are now being picked up from the swing-disk and written on a tape 4 times daily for CDC 6600 processing (for Techniques Development Laboratory).

4. Ship dictionary was screened to eliminate inactive ships and add active ships. Currently there are 1030 ships in the dictionary.

The following are operational changes on IBM System 360 #3:

1. A great deal of work was involved in programming the Interdata computer and Varian electrostatic recorder successfully in order to produce maps and radiosonde plots on the Varian at speeds less than one tenth the time required through standard facsimile channels.

Projects in progress:

1. New CCAP Assembly.

2. Program for handling 2400 bisynchronous lines with Tokyo, (due in July 1).

3. New surface decodes referencing a dictionary of 4800 stations.

4. A major and comprehensive effort to decode, correct and encode upper-air reports. Also decode, display, change and account for all kinds of weather messages.

5. Interdata program to increase the speed of map production on the Varian to over 30 times faster than the time required through standard facsimile channels.

D. Operations Branch

1. The principal activity during this period was normal maintenance as well as improvements to existing operational IBM 7094/II programs. Included was the preparation and testing of programs, using the NMC monitor system, for the June scheduled GARP data collection. In addition, system 360/30 jobs were needed to generate facsimile transmissions for this project.

2. Much time and assistance was provided to the EFD staff to modify programs required to process an extended PE forecast on the IBM 7094/II. This extended forecast is made at 12Z only, and is a continuation of the NMC forecast from 48 to 84 hours. This task involved program changes as well as new programs for processing on the IBM 7094/II. With this change, an EFD 5-day forecast is now made seven days a week and the prior 5-day

forecast at 00Z has been discontinued.

3. With the addition of another system 360 computer, there was the need for the generation of a special software operating system for the NMC System 360/30 (the other IBM 360 systems are rented). This disk operating system (DOS) was needed for the running of the facsimile programs in the foreground area (FI) and all NMC operational jobs in the background area (BG). The DOS library disk pack has only a minimal operational library and work area. The remaining portion of this disk pack is allotted for storage of map backgrounds used by the facsimile programs. Since this system 360/30 has no card reader/punch, all operational job control cards needed for execution are read from tape unit 180. The job control card print-out has been by-passed in the DOS and are only logged on the 1052 keyboard typewriter. A shared 1403 printer is presently being used for operational jobs that require printed output. These jobs are in the process of being changed so that the system 360/40 can have the printer available for its more frequent usage.

E. Electronic Equipment Branch (EEB)

1. Digital Plotter/Printer (Varian/Interdata) is developing well with close collaboration between EEB and DAD programmers. With continued modification of program, a speed improvement of 30-45 times over current speed is possible. Central Region at Kansas City and the Hurricane Center, Miami are planning to acquire this device as remote terminals which are to be driven by the IBM 360/30 at NMC.

2. Digital Facsimile Interface - DFI #2, with the Digitizer/Scanner adapter, is due to arrive at NMC (Suitland) in August 1970. The Scanner will enable us to input hard copy charts into the computer via the DFI. The DFI #2 is to be attached to the multiplexor channel of IBM 360 System #2, and will serve as a backup.

3. Uninterruptible Power. The Uninterruptible Power System (UPS), having long been on the NMC shopping list, is to soon become a reality. A contract has been awarded to purchase this power conditioning equipment which will afford protection to NMC's most sensitive electronic hardware, e.g. computers and associated peripheral devices. Operational use is planned for by November 1970. Power outages and surges are a particular source of computer problems with all ESSA groups at NMC (Suitland).

4. Data Plotters - Digifax. The meeting of operational schedules by these two systems continues to be amazingly consistent. There is no limitation foreseen on the operational life of these two systems with the exception perhaps of the delicate mechanical printers used on the Data Plotters. The replacement parts for the printers are specially manufactured and are becoming much more expensive, although still available.

III. DEVELOPMENT DIVISION

A. Primitive Equation Prognostic (PEP) Model - Operational Changes

Annotated table of principal changes in PEP model during the first half of 1970:

12Z	March 10	Initial boundary layer temperatures determined from thickness of boundary layer for high elevation (above 850 mb) grid points (See III.B.).
		Dew points computed and output for mandatory pressure levels up to 400 mb inclusive. (See NMC Office Note #36 for details.)
12Z	March 19	A number of physical and mathematical changes were introduced to induce more rain to fall from the PEP model. (See III.C.)
12Z	June 1	A smoothing of the initial relative humidity was deleted. (See III.C.) [Stackpole]

B. PEP Boundary Layer Temperature Initialization

As was mentioned in the Semi-Annual Report for Second Half 1969, Item III.B., some difficulties still existed in the use of analyzed surface temperatures to specify the initial temperature of the boundary layer. These were mainly associated with high and rugged terrain areas where the actual elevation (at which the surface temperature is measured) may differ considerably from the grid point terrain internal to the PEP code.

These difficulties (generally a too warm initial boundary temperature, since observation stations are in valleys) were substantially alleviated by the device of determining the boundary temperature hydrostatically from the thickness of the layer when the PE ground is above the height of the 850 mb surface. Otherwise, for low terrain, the temperature is found by interpolation between the surface and 850 mb temperatures as described previously. This procedure became operational 12Z March 10, 1970.

C. Quantitative Precipitation Section Modifications

As noted in the Semi-Annual Report for Second Half 1969, Item V.A., the laminated (three layers of moisture) PEP model had a distressing tendency to produce too little rain. The immediate cause of this was the change from an 80% to 100% relative humidity saturation criterion. Such a reduced humidity for saturation could have been reintroduced. Since the relative humidity forecasts themselves were rather good, attention

was given to finding ways of obtaining more water out of the model rather than to degrade the humidity forecasts.

Three such methods were found. They can be characterized as having a mixed meteorological and mathematical character, and are strongly interrelated.

1. The saturation precipitable water is computed every other timestep rather than hourly as previously done. This, in conjunction with Item 3 below, would allow for precipitation from air that was undergoing a short-term cooling and warming cycle.

2. The moist convective adjustment was expanded to include the boundary layer. In that the effect of such an adjustment would always be to cool the boundary layer, and possibly also the layer above it. This, in conjunction with Item 3, will augment the rain.

3. Retention of orographically and convectively induced supersaturation. If a layer in the model is cooled (by any means), its relative humidity, upon recomputation of the saturation precipitable water, will increase. In former procedures, any supersaturation that resulted was suppressed - this was for reasons of stability in the one-layer moisture model; with the elimination of this constraint, more rain can and indeed does fall from the model. It has a physically reasonable source.

These changes were introduced 12Z March 19, 1970.

Another potential source of rain (at least for the first 24 hours or so of the forecast) was uncovered in the handling of the initial relative humidity analysis. The analysis is designed to give values of nearly 100% for areas of present observed rain. These are frequently small-scale. In the manipulations of the initial humidity analysis, to prepare it for the model's use, a considerable smoothing of the analysis occurred that reduced these small-scale areas to well below saturation. Thus, the model would fail to forecast rain even in its initial stages, where precipitation was occurring at the initial time. By bypassing the smoothing procedure, a gratifying increase of rainfall was forecast in areas observed to be raining at the initial time. This procedure became operational 12Z June 1, 1970. [Stackpole]

D. New Semi-Global Operational Model

Detailed plans have been completed on the creation of a new operational primitive equation baroclinic model. The forecast area will be the entire Northern Hemisphere. However, the extent can be made global with a minimum of additional effort. The finite differencing method has been developed for spherical coordinates on a latitude-longitude grid. The model will consist of approximately nine layers with a horizontal grid distance of about 2.5 degrees of latitude and longitude. The final horizontal resolution that will be adopted will depend upon the computer program efficiency that can be obtained.

Due to a need for further developmental work, the non-linear instability theory will not be incorporated into this model. Present plans are to utilize the global analysis technique which fits data to a set of Hough functions in the horizontal dimensions and natural orthogonal functions in the vertical. (See Item III.L.).

The basic physics will be the same as in the current six-layer PEP model, in so far as this is possible. However, more refined physical computations can be included with a minimum of coding effort.

FORTRAN programs for the major portion of the forecast sections have been completed and testing is under way. [Stackpole]

E. PE Data - Clear Air Turbulence (CAT)

An attempt is being made to provide "in house" guidance to the Aviation Forecast Branch of NMC/A&FD for clear air turbulence forecasting. Eighteen and twenty-four hour PE forecasts of wind speed, horizontal wind shear, and vertical wind shear are being used as guidance. The data are obtained from the mandatory pressure levels - 700 mb to 250 mb. Results are being evaluated by A&FD. [Campana]

F. Initialization Experimentation with the Operational PE Model

A series of consecutive 12-hour PE forecasts has been completed which do not utilize the balance equation. (See NMC Activities Report for Second Half of 1969, Item III.E.). Unfortunately, the initial wind errors incurred by this method of correcting the 12-hour forecast wind field became intolerable after several analysis-forecast cycles. We found that the source of error resides in the manner in which the analyses are expanded from the NMC octagonal grid to the so-called PE forecast rectangular grid. Work on this particular experiment will be discontinued until the analyses can be generated on the rectangular grid.

Another experiment is being conducted which by-passes the use of the balance equation. Forecasts will be produced with the operational PE model using the objectively analyzed geopotential heights and winds. Only the rotational part of the analyzed winds will be used. The previous 12-hour forecast divergent wind component, valid at initial time, will be included (as is done in the present operational method). A numerical device which damps high frequency noise will be used during the first several hours of the forecast. The present operational wind analysis technique uses a geostrophic first guess. A plan has been made to replace this with a more accurate approximation. [Brown, Campana]

G. Short and Long Wave Radiation Studies

With an eye towards the future, a study of the fluxes of short and long wave radiation where cloud layers can be included was undertaken and some computer programs were also written. At present, only water vapor is being considered with the short wave absorption data adapted from Manabe, the long wave emissivity data from C. D. Rogers, and the modeling (a straightforward finite difference integration of the appropriate flux transfer equations). Although it is anticipated that such computations won't be operationally feasible (too long to compute), they may serve as a standard, of sorts, in which to check simpler calculations. [Stackpole]

H. RSG Instability and Decoupled Grids in Operational PEP

Programming of these two related, but separable problems, continued during the period with mixed and inconclusive results. The decoupled grids, in the PE, show a rapid growth of unstable solutions. While the decoupled grids plus RSG time smoothing show a rather rapid loss of internal and kinetic energies. Unfortunately, the possibility of programming errors cannot be eliminated as yet and the press of higher priority duties have forced a temporary abandonment of this effort. [Stackpole]

I. RSG Instability Tests on a PE Barotropic Model

Tests have been made of the Robert-Shuman-Gerrity (RSG) instability theory on a PE barotropic model. A differencing method which incorporated the ideas of this theory were found to be superior (from a numerical stability standpoint) to a comparable method which did not incorporate these ideas. The tests also indicate that a good balance of the initial data and care in treating the lateral boundaries are very important in maintaining numerical stability for the numerical integrations out to ten days. [Brown, Shuman, Gordon]

J. Boundary Layer of PE Model

Tests have been continued on various boundary layer quantities (see Semi-Annual Report for Second Half 1969) in order to define surface frontal positions more objectively. The delineation of weak systems is still a problem. However, we have had some satisfactory results in delineating strong thermal discontinuities. [Campana]

K. Limited-Area, Fine-Mesh PE Forecast Model (LFM)

The LFM has been updated to incorporate all of the physical features of the current NMC primitive equation operational model. Two test cases have been run successfully; the first test used initial data for 1200Z on March 3, 1970, and the other used data for 1200Z on April 4, 1970. In both cases, NMC operational analyses were used as a base from which initial fields were extracted and then interpolated to the half-mesh grid used in the LFM. Subjective estimates of the 12- and 24-hour forecasts, particularly the precipitation forecasts, show some improvements

when the LFM forecasts are compared to corresponding ones from the operational model. In these cases, any improvements can be attributed to the increased horizontal resolution used in the balancing and forecasting routines.

In order to increase the resolution in the input data, work is presently underway to construct a complete fine-mesh package in which analyses, initialization and forecasting are done on the LFM grid. This work also involves providing mountains, drag coefficients and land-sea contrast fields for the higher resolution grid. Since moisture and precipitation forecasts may benefit most by the fine-mesh treatment, we have been anxious to provide a high resolution moisture analysis for the LFM. To accomplish this goal, relative humidities are being analyzed directly in the sigma-coordinate system using conventional radiosonde data augmented with data inferred from surface reports of relative humidity, cloudiness and present weather. While most of the preliminary work has been completed some programming is still yet to be done before the entire package can be assembled and tested. [Howcroft, Desmarias]

L. Spectral Analysis and Forecasting

Modifications were incorporated in the Hough analysis program to permit spectral analysis of NMC operational grid-point analysis and forecasts to serve as first-guess coefficient-sets for Hough analysis. The program was further modified to provide better resolution in the polar regions.

A report describing the analysis method is almost complete. Also, some illustrations have been generated using a Stromberg-Carson microfilm recorder.

Hough function analyses have been performed on 1200Z NMC operational analyses for 19 days at 14 pressure levels. Empirical orthogonal pressure functions for each of the Hough coefficients, to wave 24, have been obtained and various groupings tested to determine the effect of horizontal scale on vertical structure. A preliminary evaluation indicates that for middle and short wavelengths, vertical structure is relatively constant. While significant differences occur for the zonal and very long waves. A set of functions determined from these experiments will be incorporated into a three-dimensional hemispheric analysis program. The initial version will produce analyses at levels from 1000 to 30 mb. [Flattery]

M. Global Semi-Implicit PE

Two predictions were made in the previous semi-annual report: (1) solving the Helmholtz equation on a sphere would present no major problems; (2) the CFL type linear instability would be a problem. (1) was correct; (2) was half right. (2), however, was also curable - the partial tendencies, the tendencies from the advective terms, were longitudinally smoothed in an equal area scheme analogous to the methods used for the explicit forecast models. This smoothing is done before the partial

tendencies are used to form the forcing function for the Helmholtz equation and it successfully cleared up the CFL instabilities. Prediction (1), relating to solving the Helmholtz equation, was half right in the sense that, although the solution by relaxation converged to what appeared to be a correct solution, the time required to do the relaxation was so great that the advantage of taking one hour (rather than 10 minute) time-steps was completely wiped out. Although some effort was expended at speeding up the relaxation, this specific mathematical problem remains with us. [Stackpole]

N. Fine Mesh Forecast Model

1. A paper describing the application of a semi-implicit integration technique to the limited-area, fine-mesh, PE barotropic model discussed in the previous semi-annual report has been accepted for publication in Monthly Weather Review (MWR).

2. Further work on an extension of the limited-area fine-mesh model to a multi-layer baroclinic version has been suspended pending the outcome of investigations described in Item P below.
[Gerrity, McPherson]

O. Finite Difference Formulation

1. An analysis of non-linear instability has been published in MWR (Robert, Shuman, and Gerrity: January 1970).

2. Experiments designed to examine certain aspects of numerical stability, in the light of the Robert-Shuman-Gerrity (RSG) theory using noisy data and a variety of finite-difference systems in one and two space dimensions, have been concluded. Relative stability was achieved in one dimension by the application of space-time filters to undifferentiated coefficients in the non-linear terms. The two-dimensional results were not as conclusive. Documentation in the form of NMC Tech. Memo No. 48 is being prepared.

3. Investigations continued along the lines suggested by Grammeltvedt (MWR 97:5). The first objective is to replicate Grammeltvedt's results for four of the difference systems that he tested. Secondly, these results are being examined in the light of the RSG theory, and also with regard to the impact of boundary conditions. Finally, using the RSG theory and increased understanding of the role of boundary conditions as guides, attempts will be made to achieve relatively greater stability in the four systems.

Coding has been completed, and success has been achieved in replicating Grammeltvedt's results for one of the difference systems. Analysis is under way. [Shuman, Gerrity, McPherson, Polger, Brinkley]

P. Implicit Integration Methods

1. The semi-implicit integration technique, described in the previous semi-annual report, has been combined with a 'staggered' grid lattice and the concepts of non-linear instability control arising from the RSG theory and subsequent experiments (see Item O). The resulting difference system, in which dependent variables are staggered with respect to each other (Lilly: MWR, 93:1), requires only one-fourth the usual number of grid points for a given spatial truncation error. Combining this reduction with the semi-implicit integration technique, which allows a computation to proceed approximately four times as rapidly as comparable explicit methods, yields a potential time advantage of sixteen-fold. The combined difference system has been applied to a PE barotropic model on a rectangular quasi-hemispheric polar stereographic projection. Three cases have been integrated to 72 hours and are being analyzed. One case has been integrated to 30 days without encountering numerical instability. Documentation is being prepared.

2. A two-layer baroclinic model using Phillips' sigma coordinate system has been designed to demonstrate the feasibility of the semi-implicit integration technique in a multi-level framework in which internal as well as external gravity waves are allowed. The initial design follows the ideals of Robert of the Canadian Meteorological Service. Coding of an explicit version of the model, incorporating the 'staggered' grid concept described in paragraph 1, has been completed and debugging is underway. Coding of the implicit version is also underway.

Investigations are continuing as to alternate formulations of the vertical coordinate. [Gerrity, McPherson, Gordon]

Q. Air Pollution Potential (APP) Forecast Program

The APP program became operational, on the CDC 6600, on February 13, 1970, utilizing forecast information from the 00Z PE run plus wind, temperature and stability data from 00Z and 12Z RAOBS, and 11Z Urban Low Level soundings. Stagnation Index used to determine areas of large scaled stagnation is a useful guidance in determining high APP areas. Facsimile products are being developed for transmission over FOFAX (Forecast Office Facsimile) beginning in Spring 1970. Details about the forecast model and output package are documented in Weather Bureau Technical Memorandum NMC 47. Stagnation index forecasts out to 48 hours from the 12Z PE run are now being evaluated. The stagnation index forecast model will include an indexed array of data consisting of: (1) lifted index, (2) 850 mb vertical velocity, (3) boundary layer wind, (4) 500 mb absolute vorticity change, (5) relative humidity (sfc-500 mb), (6) wind speeds 5000 feet above the station elevation and (7) 12-hour temperature change 5000 feet above the station. These data have specified critical values which have been determined during high APP episodes.

A computer program is being written to compute 00Z mixing heights, transport winds and ventilation. Also selected soundings will

be automatically plotted on the CDC 6600. Mixing heights and bases and tops of inversions will be annotated on the soundings.

A verification and climatological program is also being developed to evaluate the APP program. [Gross]

R. Mountain Flow

The study of flow over mountains was continued using time dependent primitive equation two-dimensional multi-layered models. The scale of the flow was assumed small enough so that the Coriolis acceleration could be neglected. The adiabatic flow was calculated utilizing the equations written in sigma coordinates.

In the first phase of the research, which was completed during this period, the flow was assumed hydrostatic. Theoretically, this constraint is seen to hit at the heart of the mountain lee waves. Nevertheless, qualitatively good agreement was found between theoretical linear non-hydrostatic solutions and the numerical integrations using this model. The model also simulated the characteristics of large-amplitude flow with jumps.

In order to overcome the difficulties of the hydrostatic model, several versions of non-hydrostatic, primitive equation models have been coded. A one-dimensional version was coded to extensively investigate the effect of the lower boundary conditions, which appear to be critical. To date none of the two-dimensional versions is entirely successful, with the difficulties arising from the lower boundary condition when mountains are included and/or the use of the sigma coordinate system. [Collins]

S. Global Primitive Equation Forecast Model

Work was begun on a global three-layer version of NMC's six-layer primitive equation operational forecast model. This new model will have a boundary layer 100-mbs deep, two layers in the troposphere, with a tropopause at 100-mbs pressure. The latitude-longitude grid has been chosen as 3.75 degrees (N=24 grid lengths from equator to pole). The input and output programs have been written and checked out. The forecast program is being checked out. It is anticipated that initial data will be global multi-level pressure surface winds and heights obtained from Flattery's Hough function analyses. (See Item III.L., also previous semi-annual reports). [Vanderman, Hirano]

T. Global Forecast Verification

Verification of 500 mb global forecasts that were run on a test case for 12Z September 26, 1969, has been completed. Preliminary results indicate a favorable comparison of statistics computed on the polar stereographic grid with the operational PE barotropic forecasts after smoothing.

Another encouraging result was the good correlation of Vanderman-Stackpole unsmoothed forecasts for the same time period.

A second test case was also run for 12Z February 18, 1970. Results are being documented. [Hirano]

U. Upper Air Branch (UAB)

The Upper Air Branch is engaged in a broad program of basic and applied research whose fundamental goals consist in defining the structure and circulation of the upper atmosphere and the coupling of this region with the troposphere. It is anticipated that the results of these investigations will be utilized in extended forecast models and possible forecast techniques with application to supersonic transport operations. The principal activities within this effort are:

1. Analysis of Stratospheric Data

a. Determination of Temperatures and Heights from Radiances

The computer programs for processing SIRS-B data have undergone extensive development and testing since the launch of NIMBUS IV on April 8, 1970. SIRS-B is scheduled to be implemented as the operational infrared sounding system, in place of NIMBUS III/SIRS-A, by July 1, 1970. [Woolf]

b. Evaluation of SIRS Data

Several evaluation efforts are underway, with a view to determining the compatibility of radiosonde data with SIRS retrievals obtained both by statistical regression technique (Smith and Woolf) and non-statistical iterative technique (Smith).
[Finger, Woolf, Johnson, McInturff]

c. Application of SIRS Radiance Data

SIRS radiance data for the Southern Hemisphere have been used to depict the evolution of thermal patterns in the stratosphere for 1969. The determination of temperature distribution is according to the method of Fritz (NESC). This is a cooperative effort with NESC, and its ultimate goal is the determination of (possibly different) forecasting requirements for SST operations in the Northern and Southern Hemisphere. [McInturff]

d. Applications of SIRS Retrieval Data

SIRS retrieval data (according to the method of Smith and Woolf) are being used to describe the 30-mb thermal and circulation regimes of the Southern Hemisphere winter. [Miller, Finger, Gelman]

e. Conversion to Real-Time Analysis

Programming the change-over from one-day-delayed to map-day analysis for the 70-, 50-, 30-, and 10-mb levels has continued, along with the overall reprogramming for the 6600 computer. Only 1200 GMT data will be utilized for the 50-mb chart, and 1200 GMT plus preceding 0000 GMT data for the 30- and 10-mb analyses. [Johnson]

f. Stratospheric History Tapes

The file of stratospheric analysis history tapes maintained by UAB was updated to June 1969. [Johnson]

2. Research on Stratospheric Circulation

a. Energetics

Preparation of summaries of various terms in the energy momentum budgets has continued. Seasonal and inter-annual varieties of the "pressure-work term" ($\omega'\phi'$) have been evaluated for the period Jan. 1964-Dec. 1968. The results indicate the above boundary term is as important as the exchange of eddy kinetic energy to zonal kinetic energy in the troposphere. [Miller, Johnson]

b. Stratospheric Warming

An extensive study of the mid-winter warming of December 1969, which is concerned with all aspects of the circulation changes of the stratosphere and troposphere, is in progress. [Miller, Brown, Campana, Johnson]

c. Accuracy of High-Level Temperatures

Data obtained at Wallops Island using radiosondes and rocketsondes are being analyzed. [Miller, Finger]

d. Planning for Meteorological Support of SST Operations

Forecasting requirements for the stratosphere are being investigated. [Finger, McInturff]

e. SIRS Radiance Data Interpretation

Integral radiative transfer equation has been evaluated for large family of stratospheric warming profiles, and the ratio of radiance change in the SIRS stratospheric channels, corresponding to specific amplitudes and altitudes of warming, has been found. Criteria for detection of stratospheric warmings in different stages of their evolution will be tested during warming event of December 1969. [Quiroz]

3. Quality Control

a. Quasi-real-time Notification of Operational Data Discrepancies

Programs to notify field units of data discrepancies as soon as possible after detection have begun. Both foreign and domestic land and marine data sources are being monitored. This effort is expected to bring about improvements in the volume and accuracy of the ADP data base. [Thomas]

b. Special Investigations

Several requests for special corrective actions involving isolated data problems were handled. These pertained to data that were being consistently encoded incorrectly, large sets of missing operational data and so on. Deficiencies were corrected upon notification. [Thomas]

c. Comparison of SIRS vs. High Altitude Balloon Data

A research study has begun to determine if SIRS data can replace high altitude balloon data. Some conventional data were deleted from stratospheric analyses which include SIRS data. Comparison studies are being made to determine the effects on the analyses by the loss of conventional RAOBS. [Thomas, Johnson]

IV. EXTENDED FORECAST DIVISION

A. Thermodynamic Model for Long-Range Numerical Prediction

While the present model is being tested operationally, attempts are being made to develop an improved model by refining the parameterization of the heating components, by using more realistic simplifying assumptions, or by choosing better values of the parameters that enter in the model. The highlights of the activities for the period of this report are given below.

1. A more complete derivation was made of the conservation of thermal energy equation applied to the upper layer of the oceans, including vertical transport of heat at the bottom of the layer. This derivation will be published in Tellus, Vol. 22, No. 4, September 1970. A talk was presented at the AMS-AGU Spring meetings in Washington, D. C. [Adem]

2. A new program has been prepared in which the pressure tendency equation is added to the model in order to compute the mean horizontal wind, as described in a paper in the Proceedings of WMO/IUGG Tokyo Symposium on Numerical Weather Prediction, March 1969. The program is almost complete. Numerical experiments will begin in June 1970. [Adem, Bostelman]

3. New evaluations of various heating components for the Northern Hemisphere and all seasons are being undertaken by using the most recent version of the thermodynamic model. [Adem, Bostelman]

4. Numerical experiments are being made using a geographically and seasonally variable Austausch coefficient. [Adem, Bostelman]

5. Studies are being made of the effect on the 30-day predictions of including snow, advection by mean wind, and storage of heat in the soil. Report prepared as NMC Office Note No. 40. [Adem, Bostelman, Polger]

6. Revision is being made on the radiation model that is used in the thermodynamic model. Dr. J. Adem participated in a radiation work-study group from March 30 to April 1, 1970, in Boulder, Colorado. Report prepared as NMC Office Note No. 41. [Adem]

7. A report has been submitted for publication on the computation and application of mean vertical winds, using time-averaged thermodynamic equations. [Sela, Clapp]

8. A report has been prepared on overcoming the difficulties due to the non-elliptic nature of the thermodynamic equation for small Austausch coefficients. [Sela]

B. Evaluation and Adaptation of Extended-Range Numerical Predictions

1. Regression equations for specifying daily precipitation probability from prognostic 700-mb heights and 24-hr height changes have been derived individually for 108 stations and 24 half-months throughout the year from 19 years of data. One "best" equation is being chosen for each station and half-month for operational use and verification on an experimental basis.

Climatological probabilities of daily precipitation for the 24 half-months have been calculated as a by-product of this work.

2. Plans are underway to revise the computer program for obtaining daily mean error fields for a number of numerical guidance products. [Andrews, Gilman, Gelhard]

3. Displacement and development errors of PE-predicted cyclones and anticyclones are being summarized for successive two-month periods. [Posey, Green]

4. Climatology of Daily Maximum and Minimum Temperatures

Ordered arrays of daily anomalies of maximum and minimum temperatures at 108 stations, stratified by months, are being computed for an 18-year record. From these, percentile values at 5% and 95% are being determined to provide upper and lower limits as a guide to extended forecasters in avoiding predictions of highly unlikely or impossible temperature anomalies. Months of May and June limits have been completed. [Gilman, Durdall]

C. Zonally-Averaged Model

The energetics and phase relations in a two-level quasi-geostrophic zonal model are investigated using a long-term numerical time integration. Diabatic effects are included through simple Newtonian heating, and frictional dissipation is introduced at the surface and the interior.

The major assumption concerns the non-linear terms of the vorticity equation which are parameterized by a potential vorticity diffusion process. [Sela]

D. Programming Support for Operations and Research

1. Revision of Extended Forecast System

A new daily extended forecast guidance system, based on 12Z initial data, was put into operation February 9, 1970, including: daily sea-level pressure, 500 mb heights and anomalies, 1000/500 mb thicknesses and anomalies, Max/Min temperature anomalies, and precipitation

probabilities (to 120 hours); observed 5-day mean sea-level and 700-mb charts with indices and pressure profiles, and observed daily indices; forecast 5-day mean 700-mb heights centered three days after initial day; and statistical objective 5-day mean temperature and precipitation anomalies for periods centered five days after initial day. Conversion of this system from the IBM 7094 system to a CDC 6600 system, with Varian graphical output, is planned. [Gelhard, Hiland, Jones, Durdall]

2. Monthly and Seasonal Forecast Support

Current work includes computation of composite precipitation maps corresponding to a special classification of 24 temperature types. Revision of a program for monthly and seasonal 700-mb height and sea-level anomaly regression forecasts for calendar months, using data from 1947 to the present was completed. Future work will include complete reprogramming of the 30-day guidance material. [Gelhard, Durdall, Jackson]

3. Work is progressing on an independent system to collect observed daily United States and Alaskan temperature and precipitation data from the IBM 360 ADP files (needed for verification of forecasts at various time ranges). [Taubensee]

4. Other planned work for operations or research includes: computation of 12Z 23-year daily sea-level means for each day of the year; processing of Northern Hemisphere GFDL data for each calendar month on transport of heat by transient eddies; reprogramming the method for obtaining daily sea-level analogs. [Gelhard]

E. Vertically-Integrated Primitive Equation Model

A vertically integrated PE model is being designed for application to the extended range. The integration, with respect to the vertical coordinate, introduces eddy and boundary terms. The major problem, in this approach, is the parameterization of the eddy terms and the vertical structure.

Various coordinate systems are being studied with respect to their effects on the complexity of the parameterization problem. [Sela]

F. Objective Prediction of Sea-Surface Temperature

A numerical method was developed for predicting mean sea-surface temperatures a month in advance. This shows lower root-mean-square errors (RMSE) than with the use of normal temperatures, based on a test sample of 12 months for 100 points in the eastern Pacific. [Namias]

V. ANALYSIS AND FORECAST DIVISION

A. Quantitative Precipitation Forecast Branch

1. Verification of Primitive Equation Model Precipitation (PEP) Forecasts for the United States area.

Wintertime (1969-70) PEP forecasts of measurable precipitation at 12-24, 24-36 and 36-48 hours for the 60-station A&FD grid have been verified by individual stations. These are mapped and analyzed on Figures 1-4.

a. Comparing these maps with those of the previous winter emphasizes the deterioration in scores that occurred since the change was made to the "Laminated PEP" on October 30, 1969.

b. About 14% fewer precipitation occurrences were observed this past winter as compared with the previous one. This may account for part of the poorer performance.

c. Overforecasting was still evident over all of the western United States -- in some areas it became extreme.

d. PEP underforecast over most of the central and eastern United States where this had not been the case with the single-layer model.

e. Moderately good scores still prevailed over the Pacific Northwest. Threat scores seem to have been affected least, in that region, by the model change. [Gordon]

Note: On March 19, 1970 - after this verification period - several changes were implemented in the "Laminated PEP" in an attempt to improve the precipitation prediction capability of the model. (See III.C.).

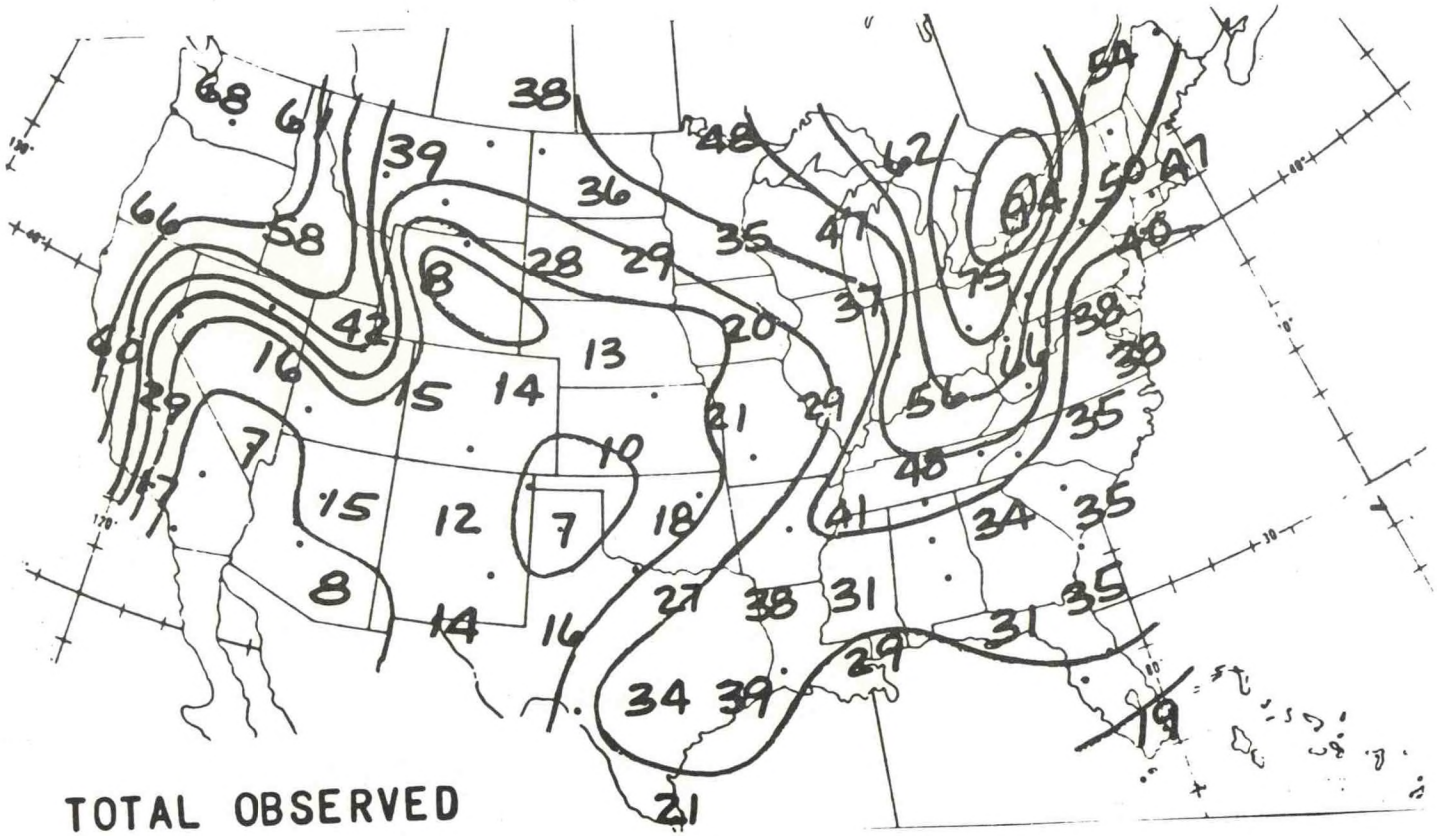


Figure 1. PEP Verification - Dec. Jan. Feb. 1969-1970

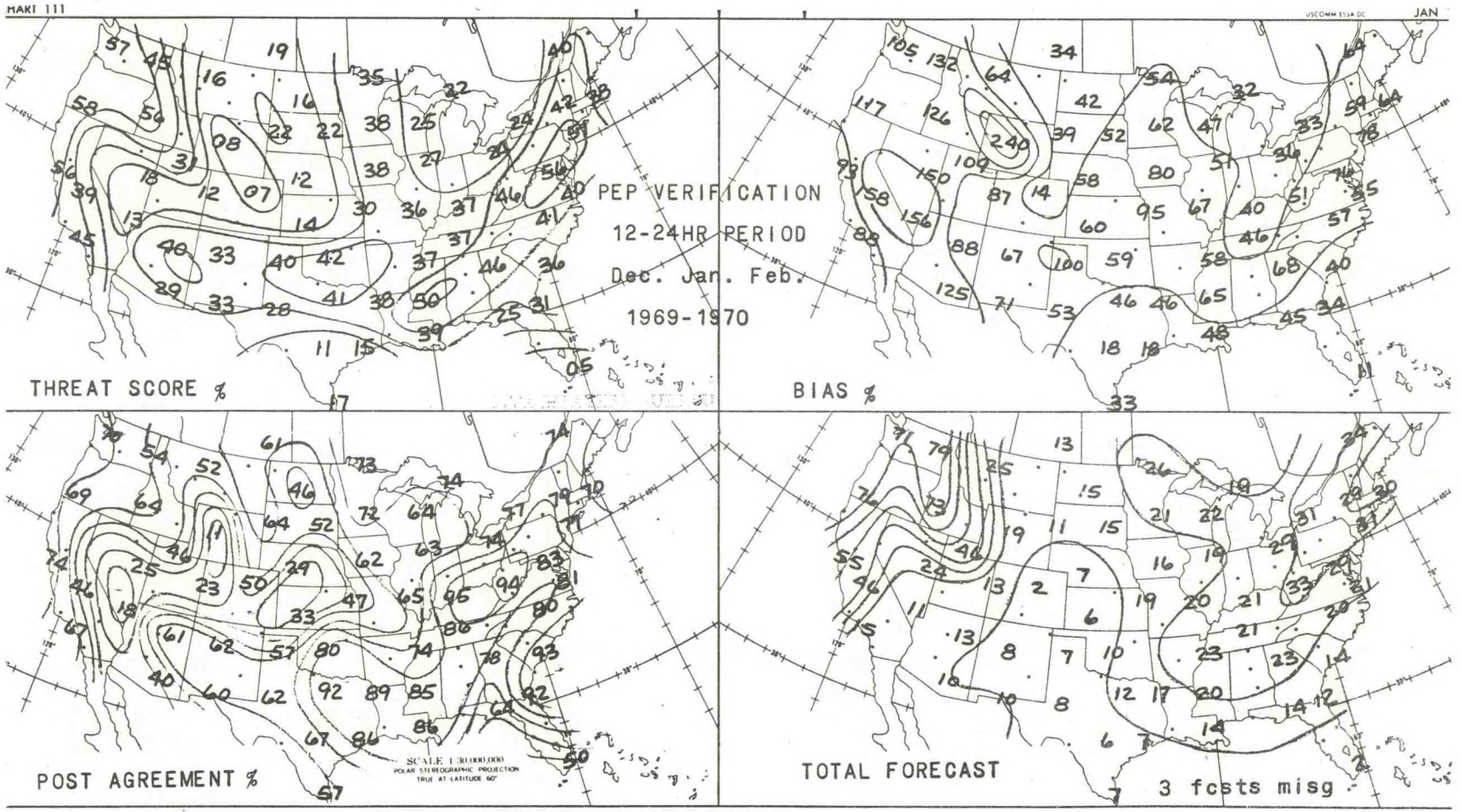

MAKI 111
USCOMM ESSA DC
JAN
PEP VERIFICATION
12-24HR PERIOD
Dec. Jan. Feb.
1969-1970
THREAT SCORE %
BIAS %
POST AGREEMENT %
TOTAL FORECAST
3 fcsts misg
SCALE 1:30,000,000
POLAR STEREOGRAPHIC PROJECTION
TRUE AT LATITUDE 60°

Figure 2.

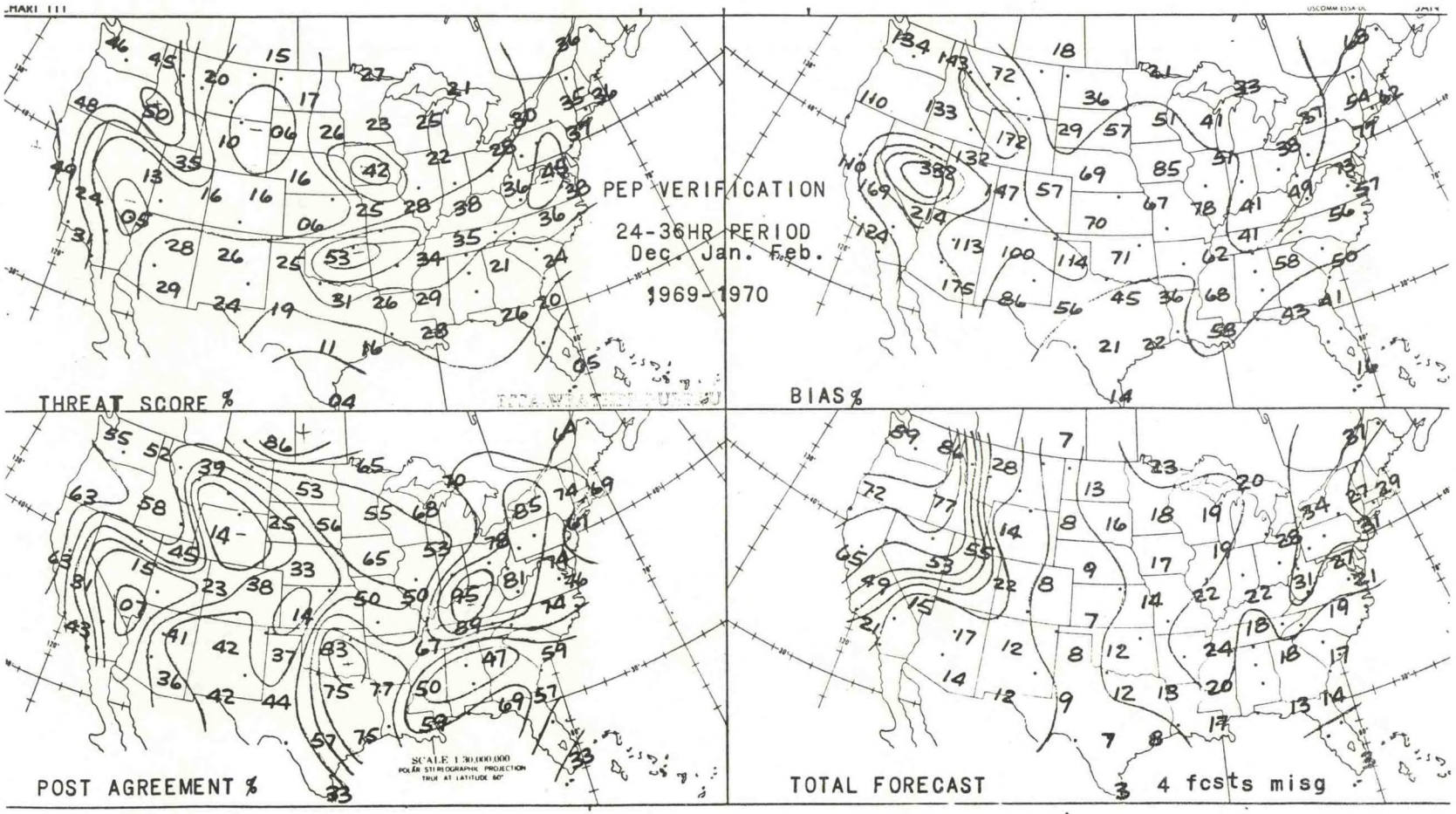

PEP VERIFICATION
24-36HR PERIOD
Dec. Jan. Feb.
1969-1970
THREAT SCORE %
BIAS %
POST AGREEMENT %
TOTAL FORECAST
4 fcsts misg
SCALE 1:30,000,000
POLAR STEREOGRAPHIC PROJECTION
TRUE AT LATITUDE 60°

Figure 3.

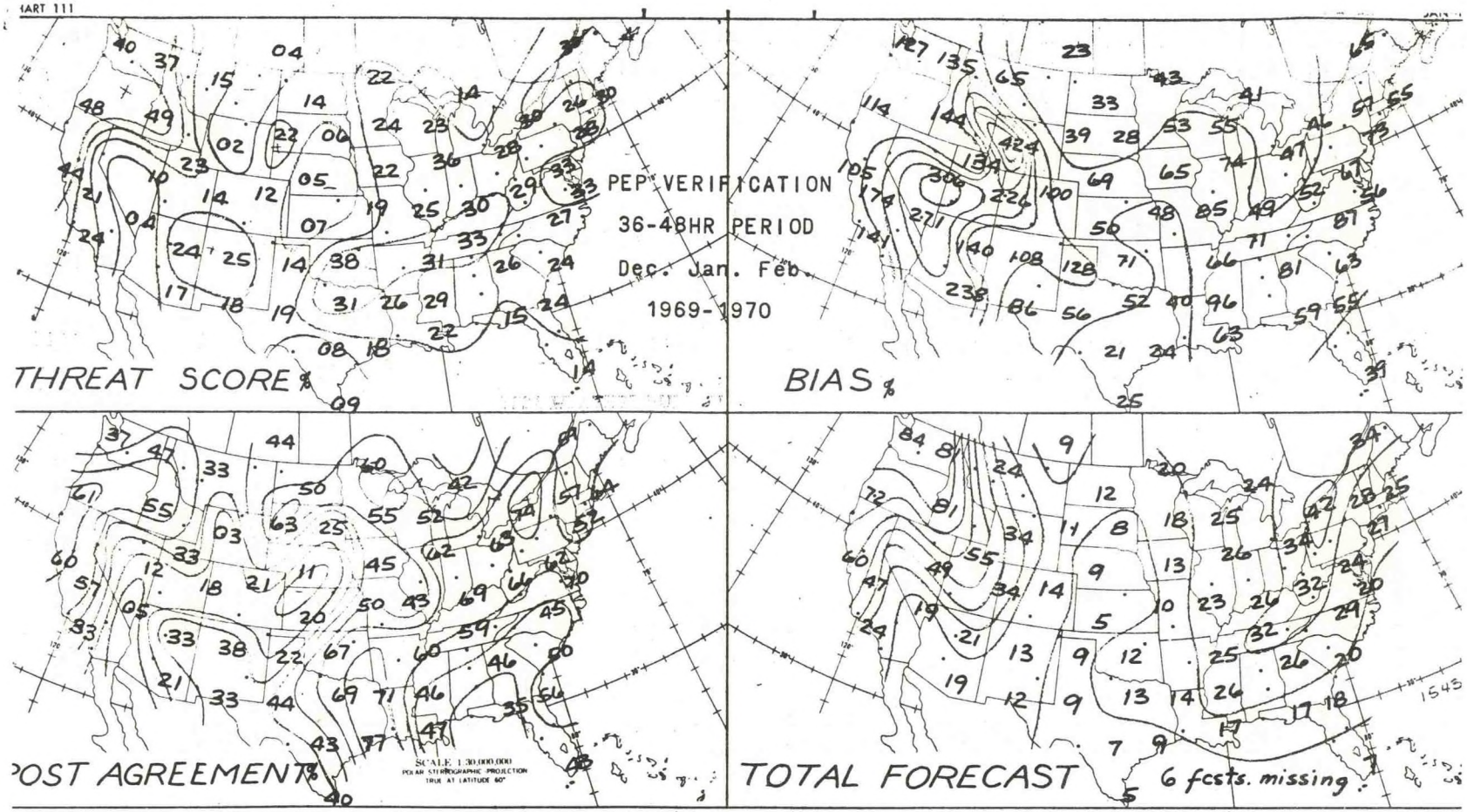

PART III
PEP VERIFICATION
36-48HR PERIOD
Dec. Jan. Feb.
1969-1970
THREAT SCORE %
BIAS %
POST AGREEMENT %
TOTAL FORECAST
6 fcsts. missing
SCALE 1:30,000,000
POLAR STEREOGRAPHIC PROJECTION
TRUE AT LATITUDE 60°

Figure 4.

VI. FORECAST VERIFICATIONS - Monthly Means for 1970

A. NMC Grid Area (1977 Grid Points)

	24 HOURS					36 HOURS								48 HOURS				
	PE MODEL			PERS		PE MODEL			PERS		BAROTROPIC			PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	R	H	W	R	H	W	H	W
200 mbs																		
Jan.	.74	198	17.0	272	23.9	.75	246	19.5	338	27.8				.74	287	22.3	378	29.8
Mar.	.74	190	17.2	265	23.1	.77	223	19.3	333	27.1				.77	256	21.8	369	28.9
May	.75	158	15.6	231	21.7	.78	192	17.4	293	25.7				.78	219	19.6	332	28.5
300 mbs																		
Jan.	.81	173	15.8	286	26.4	.80	226	18.8	358	31.0				.78	268	21.8	396	32.9
Mar.	.81	167	16.3	280	26.0	.82	207	18.8	354	30.8				.81	243	21.6	392	32.9
May	.81	141	14.4	240	23.6	.83	174	16.5	304	28.0				.82	200	18.9	344	30.8
500 mbs																		
Jan.	.83	120	11.2	207	19.4	.80	163	13.5	260	22.7	.62	210	16.8	.78	198	15.7	291	24.4
Mar.	.83	115	11.2	199	18.6	.83	148	13.2	254	22.1	.66	197	15.6	.81	176	15.3	283	23.6
May	.82	97	9.8	166	16.1	.83	122	11.4	213	19.3	.70	153	13.1	.82	142	13.1	242	21.2
850 mbs																		
Jan.	.74	108	10.3	142	12.9	.73	137	11.5	175	14.7				.71	155	12.8	192	15.4
Mar.	.74	99	9.7	137	12.4	.78	119	10.8	169	14.1				.76	136	12.2	188	14.9
May	.77	77	7.8	109	10.1	.78	95	8.8	140	12.0				.75	108	9.8	158	13.0
1000 mbs																		
Jan.	.70	136	15.7	163	16.2	.73	159	16.7	200	18.4				.67	189	20.2	214	18.8
Mar.	.77	109	12.3	154	15.3	.78	129	13.9	188	17.1				.74	155	16.2	205	17.9
May	.73	86	9.9	119	12.1	.77	109	11.3	152	14.4				.75	125	12.8	168	15.1

B. North America - Area 1 (195 Grid Points)

	24 HOURS					36 HOURS								48 HOURS				
	PE MODEL			PERS		PE MODEL			PERS		BAROTROPIC			PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	R	H	W	R	H	W	H	W
200 mbs																		
Jan.	.84	163	14.8	295	25.0	.81	228	18.7	366	28.9				.78	286	22.2	408	30.9
Mar.	.83	159	15.6	279	25.5	.81	203	19.1	349	29.5				.80	245	22.2	396	32.1
May	.87	118	12.7	244	22.9	.88	154	15.6	320	28.5				.86	189	18.5	374	32.1
300 mbs																		
Jan.	.87	165	15.8	342	31.3	.84	233	20.4	422	36.0				.80	298	24.4	466	38.0
Mar.	.87	167	17.7	338	33.4	.85	214	21.8	415	38.2				.83	264	25.5	467	41.0
May	.87	117	13.0	273	26.5	.89	159	16.7	357	33.1				.87	195	19.6	406	36.0
500 mbs																		
Jan.	.87	114	11.0	230	21.6	.82	167	14.2	284	25.0	.65	220	18.1	.78	213	17.0	316	26.5
Mar.	.87	111	11.6	229	22.6	.85	147	14.5	286	26.4	.76	182	16.6	.83	180	17.1	320	28.2
May	.89	79	8.6	179	17.1	.89	107	10.9	237	21.4	.79	140	12.7	.86	136	12.9	270	23.5
850 mbs																		
Jan.	.84	85	8.2	150	13.5	.79	116	10.1	180	15.2				.77	134	11.6	194	15.9
Mar.	.84	82	8.4	143	13.5	.83	103	9.9	172	15.4				.79	123	11.6	182	15.5
May	.84	66	6.8	116	10.5	.84	83	8.0	151	13.2				.82	99	9.3	163	13.6
1000 mbs																		
Jan.	.81	111	13.0	177	16.4	.81	138	14.9	214	18.7				.78	161	17.5	226	19.1
Mar.	.82	102	12.1	164	16.6	.82	126	13.4	194	18.3				.78	153	16.0	204	18.4
May	.79	90	10.1	132	12.8	.81	110	11.5	169	15.6				.79	132	13.7	178	15.9

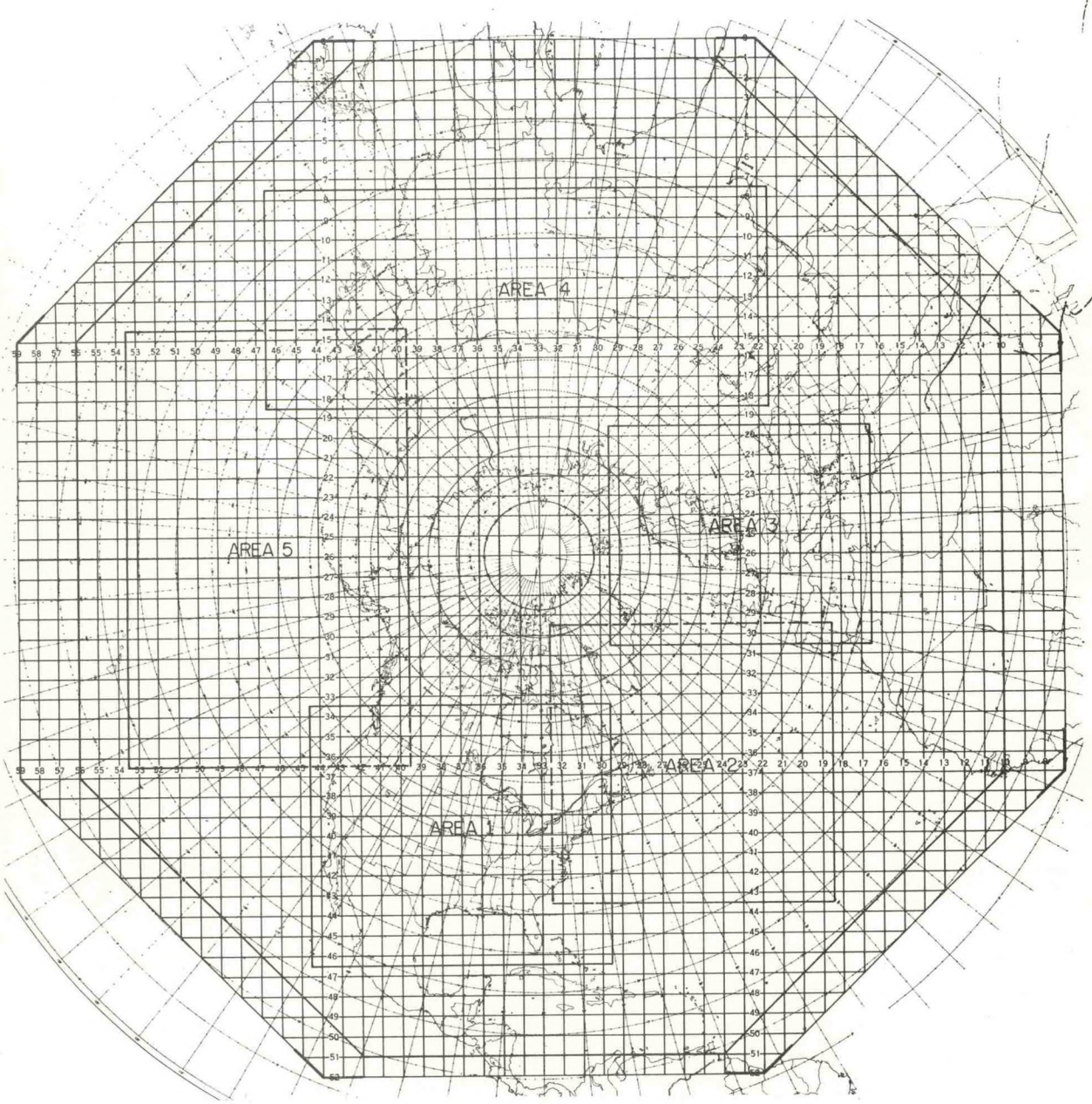
C. Europe - Area 3 (143 Grid Points)

	24 HOURS					36 HOURS								48 HOURS				
	PE MODEL			PERS		PE MODEL			PERS					PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	BAROTROPIC			R	H	W	H	W
200 mbs																		
Jan.	.83	173	16.0	309	28.1	.80	236	19.6	380	32.5				.78	292	23.0	444	36.1
Mar.	.83	152	14.9	280	24.9	.85	189	17.5	359	30.2				.84	228	20.3	411	33.2
May	.81	145	14.6	249	23.1	.82	183	17.1	315	27.6				.81	222	19.9	357	29.9
300 mbs																		
Jan.	.86	177	17.1	353	33.4	.83	240	21.2	434	39.0				.79	309	25.5	497	42.6
Mar.	.89	161	16.3	368	34.3	.89	210	19.9	465	41.3				.86	264	23.9	524	44.9
May	.85	156	16.3	303	29.4	.85	198	19.5	382	34.9				.83	245	22.8	432	37.8
500 mbs																		
Jan.	.84	129	11.7	241	22.6	.80	181	15.1	304	27.1	.70	210	18.4	.77	234	18.3	349	29.8
Mar.	.89	121	11.8	270	24.9	.88	158	14.4	341	29.9	.79	202	17.5	.85	201	17.4	385	32.7
May	.86	108	10.9	211	20.2	.85	142	13.4	270	23.9	.71	193	16.6	.86	176	15.9	310	26.3
850 mbs																		
Jan.	.78	103	9.0	160	14.6	.76	134	10.9	203	17.7				.73	165	12.7	230	19.4
Mar.	.85	95	8.5	176	15.0	.86	117	10.2	227	18.4				.84	139	12.1	255	20.0
May	.82	78	7.4	133	11.9	.81	102	9.0	171	14.3				.79	126	10.6	197	15.7
1000 mbs																		
Jan.	.77	109	10.5	173	16.1	.77	141	12.2	216	19.3				.72	180	14.7	246	21.2
Mar.	.86	96	9.4	185	16.4	.86	120	11.2	236	19.6				.84	144	13.1	266	21.5
May	.81	80	8.0	139	13.0	.81	103	9.6	174	15.1				.78	128	11.3	197	16.4

D. Asia - Area 4 (275 Grid Points)

	24 HOURS					36 HOURS								48 HOURS				
	PE MODEL			PERS		PE MODEL			PERS		BAROTROPIC			PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	R	H	W	R	H	W	H	W
200 mbs																		
Jan.	.76	186	17.0	276	24.1	.81	210	18.8	348	28.5				.81	243	21.5	393	30.9
Mar.	.74	172	15.7	244	20.9	.73	231	18.4	308	24.9				.78	245	20.3	343	26.9
May	.83	144	14.8	254	23.9	.83	181	17.6	327	28.7				.82	211	19.6	365	31.5
300 mbs																		
Jan.	.84	161	15.5	294	26.8	.84	205	18.1	368	31.6				.84	235	20.7	414	34.1
Mar.	.80	158	15.2	259	23.7	.78	219	17.4	327	28.5				.80	243	20.0	367	30.9
May	.85	136	14.5	259	26.4	.85	171	16.9	322	30.8				.84	197	19.4	358	33.2
500 mbs																		
Jan.	.86	108	10.4	208	19.5	.85	142	12.4	262	22.8	.70	186	15.3	.84	168	14.5	295	24.6
Mar.	.82	104	10.0	176	16.8	.78	150	11.6	224	19.8	.56	202	14.8	.82	157	13.2	248	21.5
May	.83	92	9.5	167	17.4	.84	116	11.4	210	20.5	.64	165	13.8	.82	135	13.3	231	21.8
850 mbs																		
Jan.	.60	142	14.3	131	11.4	.65	159	14.6	167	13.8				.65	174	15.4	184	14.3
Mar.	.64	124	12.1	122	10.8	.66	146	12.9	153	12.8				.70	148	14.1	164	13.3
May	.76	93	9.8	125	11.9	.76	113	11.0	156	13.9				.76	126	12.4	173	15.0
1000 mbs																		
Jan.	.53	218	27.3	163	15.6	.67	222	27.1	216	20.8				.54	283	34.9	221	18.9
Mar.	.67	138	16.4	153	14.6	.72	156	18.6	192	17.7				.68	186	22.6	201	17.6
May	.73	114	13.5	145	14.5	.73	147	15.9	183	17.3				.73	165	18.1	197	17.9

R - Correlation coefficient of forecast versus actual height change
H - Root mean square deviation of height in feet
W - Root mean square vector geostrophic wind error in knots
PE Model - Operational 6-layer primitive equation baroclinic forecast model
PERS - Persistence forecast
BAROTROPIC - Operational barotropic forecast model



Verification Areas

VII. PERSONNEL CHANGES

A. Office of the Director (OD)

1. Frank W. Burnett, Deputy Director, transferred to the Office of the Director, Weather Bureau, March 8, 1970, as Deputy Director.

2. Harlan K. Saylor, Chief, Analysis and Forecast Division, was promoted to Deputy Director, NMC.

B. Data Automation Division (DAD)

1. Frederick S. Zbar, Meteorologist, joined Statistical Techniques & Analysis Branch, February 15, 1970.

2. Armond J. Desmarias, Meteorologist, joined Programming Branch, March 22, 1970.

3. Shigemi Fujiwhara, Meteorologist, returned to Japan Meteorological Office, April 5, 1970.

C. Development Division (DD)

1. Alonzo Smith, Jr., Meteorologist, joined Development Division, March 22, 1970.

D. Analysis & Forecast Division (A&FD)

1. Jerrold A. LaRue, Branch Chief, Surface Analysis Branch, was reassigned to Washington Forecast Center, January 10, 1970.

2. William H. Metivier, Jr., Branch Chief, Charting Branch, was reassigned to Overseas Operations Division, Panama Canal Zone, January 10, 1970.

3. Theodore F. Fathauer, Meteorologist, Aviation Weather Forecast Branch, transferred to Weather Bureau Office, Anchorage, Alaska, March 18, 1970.

4. Charles R. Reid, Meteorologist, joined Surface Analysis Branch, June 14, 1970.

E. Extended Forecast Division (EFD)

1. Russell E. Jones, Mathematician, was reassigned from Computer Division, ESSA, to Computer Applications Section, March 22, 1970.

VIII. MACHINE PERFORMANCE AND UTILIZATION

A. IBM 7094/II

1. 7094/II Profile - No changes
2. Utilization - 2,832 hrs.

B. IBM 1401

1. 1401 Profile - No changes
2. Utilization - 1,680 hrs.

C. IBM 360/30 (Owned)

1. 360/30 #1 Profile

   a. Leased equipment

      1 - IBM 2803-1 Tape Control Unit 02-70

2. Utilization - 2,366 hrs. (5 months)

D. IBM 360/30 (Leased)

1. 360/30 #2 Profile - Released

   a. Released equipment

      1 - IBM 2030-F Central Processing Unit 04-70
      1 - IBM 1051-N1 Control Unit 04-70
      1 - IBM 1052-6 Printer Keyboard 04-70

2. Utilization - 1,441 hrs. (3 months and 11 days)

E. IBM 360/40 (Owned)

1. 360/40 #1 Profile

   a. Leased equipment

      1 - IBM 1443-N1 Printer 03-70
      1 - IBM 2501-B1 Card Reader 03-70

2. Utilization - 4,243 hrs.

F. IBM 360/40 (Leased)

1. 360/40 #2 Profile - 360/40 positioned where leased 360/30 was being used

   a. Leased equipment

1 - IBM 2040-G	Central Processing Unit	04-70
1 - IBM 1052-7	Printer Keyboard	04-70
1 - IBM 2911	Switching Unit (Disk)	03-70
1 - MAI 2402	Magnetic Tape Unit	06-70

2. Utilization - 637 hrs. (2 months, 19 days)

G. CDC 6600, Computer Division, ESSA

1. CDC 6600 Profile - No changes
2. Utilization for NMC work - CPU 779 hrs.
   PPU 2,011 hrs.

IX. DISTRIBUTION OF PRODUCTS

As of June 30, 1970, NMC was originating approximately 420 separate teletype bulletins per day for transmission over Weather Bureau, Navy, Air Force, and Air Transport Association teletype circuits. The Automated Analysis Branch (AAB) was responsible for the following daily facsimile transmissions:

National Facsimile Network	38
Navy Facsimile Network	2
Air Force Facsimile Network	18
International Facsimile (European) Network	26
Russian Facsimile Network	21
Forecast Center Facsimile Network	56
Weather Experimental Facsimile (WEFAX)	6
High Altitude	38
Honolulu-Southwest Pacific	43