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Numerical Weather Prediction Activities

National Meteorological Center
Second Half 1971

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SILVER SPRING, MD.

February 1972

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

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C O N T E N T S

I. INTRODUCTION

This report summarizes the numerical weather prediction (NWP) activities of the National Meteorological Center (NMC) for the last half of 1971. During that period, a limited-area fine-mesh[1] (LFM) forecasting model was implemented, an innovative initialization procedure was incorporated into the coarse-mesh[2] six-layer primitive equation (PE) model, and a comprehensive effort was begun to adapt the Air Force Global Weather Central (AFGWC) boundary layer model to function in the NMC environment. Also included in this report are summaries of recent developments in data automation and verification statistics for the LFM and PE models.

A NOAA Technical Memorandum NWS NMC-51 entitled "Forecast Verifications--Monthly Means for 10 Years (1962-1971)" is in preparation. The publication will include a discussion and comparison of the accuracy of the operational NWP models employed by NMC during the past 10 years. The verification tables, similar to those in Section VII of this report, will be included.

II. REVISIONS IN OPERATIONAL PROGRAM

A. A New Initialization Procedure for the Coarse-Mesh Primitive Equation Model

On August 23, 1971, the use of the balance equation in the initialization procedure for the coarse-mesh six-layer PE model was discontinued. In the new procedure, the objectively analyzed wind fields are interpolated from the mandatory pressure levels to the PE sigma-surfaces and then the rotational (nondivergent) component is retained. The irrotational (divergent) component is still obtained from the 12-hour PE forecast which verifies at the analysis time. This new method replaced the old technique for obtaining the initial rotational-wind component from the height field through the use of the nonlinear balance equation. This change brought the initial conditions of the forecast model into closer agreement with the real atmosphere without significantly increasing the noise level of the prediction model. A complete description of the new procedure is given in NWS Technical Procedures Bulletin No. 65, "New Initialization Procedure for the 6-layer (PE) Numerical Prediction Model."

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[1]190.5-km grid distance on polar stereographic projection true at latitude 60°N.

[2]381-km grid distance on polar stereographic projection true at latitude 60°N.

B. LFM Forecasting Model

On September 29, 1971, the LFM model became operational. A total of 65 test cases had been run before implementation. These cases were verified and compared with similar verifications from the operational six-layer PE model. (See III.B.)

C. Convective Rain in the PE Model

Convective rain, described in the preceding report, Numerical Weather Prediction (NWP) Activities, National Meteorological Center (NMC) First Half 1971, was introduced into the six-layer PE model during this period. Some of the initial numerical and scaling problems have been solved. One problem was the discovery that the model's initial conditions were sufficiently unstable, in the convective rain sense, resulting in unreasonable amounts of rain to accumulate during the first 12 hours. The problem was circumvented by excluding the amount of rain that accumulated during the first hour.

III. DEVELOPMENT DIVISION

A. Eight-Layer Hemispheric Primitive Equation (PE) Model Development

During the preceding one-half year, the major developmental effort centered on numerical problems, mainly those problems that relate to the satisfaction of the CFL (Courant-Friedrich-Lewy) linear-stability criterion under the condition of the northward convergence of the meridians, with some lesser consideration given to the meteorological quality of such forecasts as have been made.

1. The Linear-Stability Problem

To maintain a sufficiently large grid length as the meridians converge on the sphere, longitudinal averaging--the extent of which is proportional to the secant of the latitude--is performed upon the tendency fields. Thus, the length of the averaging remains constant with respect to distances on the earth, but becomes larger in terms of grid lengths at higher latitudes. In theory, this appears fine; but in practice, a dilemma arises. Near the pole, where the length of the longitudinal averaging is quite large (some 30 grid lengths end-to-end on the 2.5-degree grid), repeated application of an averaging function can and does excite waves, particularly in the wind fields, with wavelengths equal to the averaging length (and half the length). These waves are evident in the forecasts. They grow excessively and become the immediate cause of blowups of the model.

A series of forecasts with a barotropic model derived from the eight-layer model pointed out the nature of the dilemma; namely, reduction of the averaging length decreased both the wavelength and more importantly the amplitude of the excited waves. However, the amount of reduction that was necessary to bring the excited waves under control caused the computations to fall into the CFL instability region. The excitation was dependent upon the form of the averaging function--a rectangular-averaging function was the cause of the difficulties alluded to above, while a trapezoidal- or a triangular-averaging function showed no trace of polar-wave excitation or CFL instabilities.

However, our parallel experience with the baroclinic model has not been as fortunate. As we anticipated, the rectangular-averaging function generated spurious waves of a wavelength approximately equal to the length of the averaging function which typically destroyed the forecast in the 36- to 48-hour period. A series of runs were made using a smaller rectangular-averaging length. The time step was reduced from 10 to 7.5 minutes. These runs are described below. One result was not anticipated; the trapezoidal-averaging function that was successful with the barotropic model did no better. That particular function generated spurious polar waves and required 7.5-minute time steps to do so. (The rectangular-averaging function was at least marginally successful with a 10-minute time step until the bogus-wave problem obliterated everything else.) Tests are now underway using a triangular-averaging function. Test results are encouraging, but final results are not available.

As a means to obtain forecasts that are somewhat more economical and reliable, a model with a 5-degree latitude-longitude grid was constructed (all other aspects of the model remained the same). Although the intent was to investigate meteorological behavior, the model numerics were also of interest. The same sequence of tests and problems was investigated. However, both the rectangular- and trapezoidal-averaging functions excited polar waves, but neither was sufficient to destroy the forecasts by 48 hours, even using the 10-minute time steps. A favorable outcome was indicated when the use of a triangular-averaging function did not generate periodicities in the forecast.

2. Meteorological Considerations

A series of three 2.5-degree grid forecasts and analysis cycles were run using compromised numerics. The first series tested the stability of the Hough-Flattery-Johnson (HUFLATSON) spectral-analysis system (see III.C.), using a 12-hour forecast as a first guess; the second series analyzed the quality of forecasts. Unfortunately, the period of the data set was singularly uninteresting (1200Z on February 18, 1970). A large high pressure system was situated over virtually all of the conterminous United States. At the time, the analysis did not include surface observations, so little effort was expended in low-level verifications.

Subjectively, the 500-millibar charts showed about the right behavior for the pattern motion. There were two problems. The first problem, involving a lowering of all heights by 60 to 70 meters, was traced to a deficiency in the radiation package of the model. The entire Northern Hemisphere troposphere cooled by 1.5 to 2.0 degrees K. in 48 hours! The other problem, potentially more serious, was that the model tended to hold an analyzed 500-millibar low pressure system stationary at the pole during the forecast while the atmosphere (and the model a few grid rows south) moved the low away. At present, it is hoped that a solution to the numerical pole problem may also resolve the other problem.

A companion run to the above forecast and analyses cycles was made with the operational six-layer model, but using the HUFLATSON analyses for 0000Z on February 19, 1970, that correspond to the second run of the hemispheric series. Again, the six- and eight-layer forecasts were more or less the same, but the aforementioned problems with the heights and the pole did not show up in the six-layer model.

With the imminent development of the HUFLATSON analysis to include surface data, more thorough verifications will be undertaken.

(Stackpole)

B. Limited-Area Fine-Mesh Model (LFM)

The LFM was introduced into the NMC operational schedule at the 1200Z run on September 29, 1971. A total of 65 test cases had been run and evaluated in the year preceding that date, making the LFM a well-tested model. The transition from a test to an operational status was not without difficulties. The major problem has been to obtain surface and upper air data from the NMC communications computer in time for use by the LFM. This problem has resulted in some runs being missed and others being made with little or no new data given to the model. Problems in the National Oceanic and Atmospheric Administration (NOAA) computer hardware and software have also caused some LFM runs to be missed or delayed to the point where cancellation was necessary. The meteorological performance of the model has been about as expected; some of the verification figures are shown in Section VI of this report. Incidentally, those verification scores also include those runs made with deficient data.

As the model is being operated, some of its characteristics are being studied with a view toward improving the model. A change was introduced at the 1200Z run on December 1 to make the model somewhat more dry. As the season had changed from summer to autumn, it was noted that the tendency of the LFM to overforecast precipitation occurrence had increased significantly. The parameter specifying the relative humidity value at which model saturation occurs was adjusted upward from 90 to 95 percent. Further seasonal adjustments may become necessary.

We are also studying the run made from 1200Z on December 6 in some detail because a lateral-boundary problem caused the 24-hour forecast to become marred over the eastern United States. In this case, strong winds impinged upon the grid boundary over the Atlantic Ocean and gave rise to instabilities that worked themselves backward into the display area. This sort of problem is not unexpected and, in fact, will occur to some degree in almost all LFM runs. However, the effects in this instance were extreme and require special study.

Some experimental LFM runs have been made using the new initialization scheme that was developed by Brown and Campana at the NMC (see II.A.) for use in the current operational hemispheric PE model. Although the scheme worked well and the resulting forecasts were quite acceptable, some interactions with other portions of the model generated problems that must be solved before the new procedure can be incorporated into the LFM.

(Howcroft and Desmarais)

C. Spectral Analysis and Prediction

1. Further experiments were performed using Hough analyses as initial conditions for the hemispheric eight-level model. The analyses were accepted satisfactorily, and three forecasts were made (see III.A.).

(Flattery and Johnson)

2. A global three-dimensional Hough analysis program has been completed and a set of initial conditions prepared for Vanderman's three-layer global model (see III.J.). This analysis program is now run on a test basis once daily replacing the 1200Z tropical final analysis. Output consists of global height and wind fields for all mandatory levels from 1000 to 100 millibars.

(Flattery and Johnson)

3. A global spectral forecast model using Hough functions has been programmed and is in initial checkout. The model is spectral in all three dimensions with variable resolution. Initial experiments will be conducted with four functions in the vertical, 16 longitudinal waves, and

24 latitudinal waves. This truncation requires about 50 seconds per hour of forecast to run on the Control Data Corporation (CDC) 6600 computer.

(Flattery)

D. Finite Difference Formulation

The study of higher order finite difference approximations in a free-surface channel model has been completed. Experimental integrations, using idealized data and employing: (1) the standard semimomentum differencing on a coarse mesh, (2) the higher order differencing on a coarse mesh, and (3) the standard semimomentum system on a fine (one-half of coarse-mesh length) mesh, have produced encouraging results. Theory predicts that the higher order scheme should be somewhat more accurate in terms of truncation error than the standard system on the fine mesh; our experiments confirmed this. This result suggests that the higher order system may be considered as a more economical alternative to high-resolution forecasts, or as a powerful complement to them. A paper documenting these experiments, "On the Efficient Reduction of Truncation Error in Numerical Weather Prediction Models," by Gerrity, McPherson and Polger has been submitted to Monthly Weather Review for publication. Further comparative experiments have begun, using real initial data over a quasi-hemispheric rectangle, with the idea of examining the validity of the above conclusions in a real-data framework.

A stability analysis has been carried out for a scheme proposed by A. Robert for the temporal filtering of numerical time-integration methods. Both a closed-form analysis and a numerical investigation of the stability criterion were made for a one-dimensional wave equation. Results indicate that the method produces selective damping of high-frequency and computational modes at relatively little cost in additional calculation. The experiment is described in NMC Office Notes 60 and 62, "Further Properties of the Method of Time Averaging as Applied to Wave Type and Damping Type Equations" and "Some Comments on Robert's Time Filter for Time Integration," respectively.

(Gerrity, Polger, Scolnik, and McPherson)

E. Implicit Integration Methods

Documentation of work outlines in Items II.E.4. and II.E.5. of the NWP Activities, NMC, First Half 1971 report has been completed in the form of NMC Office Note 64, "The Red Herring Affair: Modified Semi-Implicit Methods Revisited." A successful method of separating the external gravity mode for implicit treatment from the internal modes for explicit treatment was devised. By both theoretical analysis and numerical integration, it was demonstrated that the method allows the external mode to be treated implicitly and is damped, while internal modes are calculated explicitly and neutrally. However, the potential time advantage available by use of this method is not sufficient to warrant its use. This line of work will not be pursued further.

Item II.E.6. of the same NWP Activities, NMC, First Half 1971 report, concerning the treatment of the geostrophic adjustment process by implicit integration methods, has been shelved indefinitely in favor of higher priority tasks.

A semi-implicit two-layer model, using Phillips' sigma-coordinate and a semimomentum formulation of spatial differencing, has been successfully integrated to 48 hours in 1-hour time steps. The results have been compared with an analogous explicit forecast. The purpose of this experiment, to demonstrate the feasibility of the semi-implicit method in a baroclinic model, has been achieved. Documentation of this effort has been provided in NMC Office Note 65, "A Semi-Implicit Integration Scheme for Baroclinic Models."

With the success of the above experiment, the effort to cast the two-layer semi-implicit model on a staggered grid has been revived. The model has been debugged, and work is continuing on a suitable initialization procedure. However, this work has been assigned a lower priority, because it now appears that the use of higher ordered differencing will prove superior to the use of the staggered grid. Documentation will be forthcoming.

(Gerrity, McPherson, Polger, and Gordon)

F. Mountain Flow

A hydrostatic two-dimensional model has been used to investigate the role of nonlinearity in the formation of rotors to the lee of mountains. For a particular horizontal mountain size and thermal structure, both the upstream windspeed and mountain height were varied to determine under what circumstances would rotors form entirely by the nonlinearities of the flow. Lee waves are not present with this model. Preliminary results were presented in a paper, "Nonlinear Influences in the Formation and Maintenance of Rotor Flow in the Lee of Mountains," given at the October 1971 meeting of the American Meteorological Society (AMS) at Salt Lake City, Utah.

To generalize the results to cases with significant lee-wave activity, a two-dimensional nonhydrostatic model was coded. The model calculations show the formation of lee waves in time. It is planned to compare these results with those obtained from the hydrostatic model and to simulate mountain flow in real-data cases.

(Collins)

G. Planetary Boundary-Layer Model (PBL)

A comprehensive effort was begun during the period of this report to adapt the AFGWC BLM (AFGWC Technical Memorandum 70-5, "AFGWC Boundary-Layer Model," Hadeen, Kenneth D., Lt. Col., April 1970) to function in the NMC environment. This model, at AFGWC, routinely produces detailed forecasts of the wind, temperature, and moisture fields at seven levels from the surface to 1600 meters above the ground over a "window" slightly larger than the conterminous 48 States. The intent of this effort is to examine the quality and utility of the PBL's output, with respect to its application as guidance for terminal forecasting, severe weather, and the air stagnation program.

The PBL model requires a detailed analysis of the thermal and moisture fields as initial data. Time-dependent boundary conditions of wind components and an estimate of cloudiness at the 1600-meter level at each hour are provided by a free-air forecast model. Output of the BLM consists of wind, temperature, specific humidity, and vertical motion at seven levels--50, 150, 300, 600, 900, 1200, and 1600 meters--above the ground.

The PBL project has been divided into three parts. The objective of each part is as follows: First, to run the program from the AFGWC model on the NMC's CDC 6600 computer; second, to design a suitable analysis procedure to provide initial data; and third, to devise an optimum output package.

NMC researchers received, through a collaborative arrangement with investigators from Drexel University, a version of the AFGWC BLM computer program in late August 1971. That version has been debugged on the CDC 6600, using input data provided on tape by AFGWC. Two 24-hour forecasts--July 3, 1970, and October 14, 1971--have been run and analyzed. Overall results have been encouraging and suggest that further effort is warranted.

(Gerrity, McPherson, Jones, Gross, Howcroft, and Goddard)

1. Planetary Boundary Layer Analysis

The NMC Boundary-Layer Analysis program provides initial temperatures and specific humidities at each of eight model levels and gives the wind at 1600 meters over a 29 x 27 grid. The analysis routine uses a modified technique developed by Barnes[3] to correct first-guess lapse rates in each layer with observed lapse rates obtained from conventional upper air soundings. The first-guess of the upper air

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[3]Barnes, Stanley L.: "A Technique for Maximizing Details in Numerical Weather Map Analysis," Journal of Applied Meteorology, Vol. 3, No. 4, August 1964, pp. 396-409.

analysis is obtained from the LFM-analyzed fields, beginning at the surface and proceeding upward to 1000, 850, 700, and 500 millibars. Raw data, obtained from upper air information, are interpolated to the levels of the model that, in turn, are used to compute lapse rates within each layer.

(Jones)

2. Display Package for the PBL Model

To evaluate the utility of the PBL, two output forms are being produced at the NMC. The first output involves plotting radiosonde observation (RAOB) soundings for a series of 30 stations near grid points in the model on Stüve diagrams from a CDC 6600 program out to 24 hours. Researchers are comparing these computer-derived data to actual RAOB soundings; in the future, researchers will make comparisons to data from towers. The other output, consisting of temperatures, relative humidities, vector wind plots, cross sections, mixing heights, transport windspeeds, relative concentrations, ceilings, and freezing-level forecasts out to 24 hours, is produced on microfilm, using the equipment available at the CDC 6600 site.

(Gross)

H. Semi-Implicit Barotropic Hemispheric Model

With the success of a multilayer (two-layer) semi-implicit model on a rectangular grid (see III.E.), interest was revived in a hemispheric one-layer version developed earlier--see NWP Activities, NMC, First Half 1970 report, III.M. The one-layer model was "dusted off," found to be in working order, and consideration immediately centered on the previously unresolved problem--the time required to solve the Helmholtz equation on the sphere. Adjustment of the overrelaxation coefficient and a reversal of the direction of the Liebman relaxation, southward rather than northward, seemed to help somewhat--but not enough.

Also, the finite difference system is being changed to the one used in the hemispheric PE model (see III.A.). The system in the first version was related to the vector-invariant form of the equations, a form which proved somewhat unsuitable for explicit spherical computations.

(Stackpole)

I. A Modified Leap-Frog Differencing System

The well-known linear stability criterion for the leap-frog differencing method for the gravity wave in the barotropic PE model is

$$gH(k\Delta t)^2 < 1.$$

Here, g is the gravitational acceleration, H is the mean depth for the fluid, k is the wave number, and Δt is the length of the time step. For adequate spatial resolution, this leap-frog differencing method requires a very short time step compared with the long periods of the meteorologically interesting motions.

In NMC Office Note 56, "A Suggested Modification of Computational Procedures for Spherical Coordinates," Shuman suggested a modification which maintains the explicit nature of the system while relaxing the above constraint to allow for a Δt that is twice as large for a given k. The idea was tested successfully in nonlinear barotropic models on a polar stereographic projection and on a latitude-longitude global grid.

The linear analysis of the modified technique has been extended to a two-layer model. After finding that the idea was valid for that model, it was tested successfully in the nonlinear two-layer version. Work is proceeding to incorporate the modification into the six-layer PE model. The success in obtaining a 48-hour forecast with a 20-minute Δt, in place of the 10-minute Δt, was encouraging. However, it was found that the amplifying computational modes, which were evident in the linear analyses, produced excessive noise. Methods to control the computational modes in this modified system are being investigated.

The number of additional calculations required in the new technique is small. Thus, the successful use of the new technique in a given forecast should result in cutting the computer requirements significantly.

(Brown, Campana, Bedient, Vanderman, and Shuman)

J. Global Forecast Model

1. Initialization

To provide initial data that are consistent with the finite difference form of the prediction model, the potential temperature at the reference level (middle of the layer) is calculated from the observed-layer thickness. It was assumed that the simple average of the wind components at the top and bottom of the layer is representative of the wind components at the reference level.

Energy statistics for the Global Forecast Model show a gradual increase in kinetic energy and a faster rate of decrease in total potential energy. There was a threefold difference in the total change during a 12-hour forecast, incorporating no mountains and using Northern Hemisphere data for February 18, 1970, which was reflected into the

Southern Hemisphere. The area averaged root-mean-square vorticity remains nearly constant; however, the divergence increases for the first 6 hours and becomes steady thereafter.

Output of realistic maps above 300 millibars is not possible because the averaging process destroys the upper tropospheric wind shear. The use of the actual wind at the reference level results in a large initial drop in kinetic energy as the wind is forced to adjust to the height field. Study and experiments to solve these problems are continuing.

(Hirano)

2. A Forecast With Global Data

The global three-layer PE forecast model on a 3.75-degree latitude-longitude grid, with sigma as the vertical coordinate, was run to 72 hours from global analyses derived from Hough functions (see III.C.). Winds and heights for 1000, 850, 700, 500, 300, 200, and 100 millibars for 0000Z on June 4, 1970, and unsmoothed global mountains were employed in interpolating initially to the model's four pressure levels--the ground, the interfaces between layers, and the top of the troposphere. Initial winds and potential temperatures for a layer are calculated as described in subsection 1. above. A convective adjustment mechanism was employed. Boundary-layer heating and friction and radiation effects <u>were not</u> employed in this particular forecast calculation. Preceding the beginning of the forecast was 6 hours of forward-backward in-time initialization calculation, using the Euler backward-difference technique during which mutual adjustment of all dependent variables is allowed. During the forecast calculation, time smoothing was employed in the form:

$$u^*_\tau = \alpha\, u_\tau + 0.5(1-\alpha)(u^*_{\tau+1}), \text{ with } \alpha = 0.5.$$

A paper concerned with this forecast, "Forecasting with a Global Three-Layer Primitive Equation Model," was presented at the Seventh Technical Conference on Hurricanes and Tropical Meteorology in Barbados during December 1971. This paper will be submitted for publication at a later date.

(Vanderman)

K. Vertical Differencing

A modification of the NMC's vertical differencing in PE models is being tested. The new system was constructed on conservation principles relative to the vertical-space dimension. With respect to vertical truncation errors, this system conserves the first and second moments of potential temperature, mass, and total energy under adiabatic conditions.

(Brown, Hirano, and Stackpole)

L. Plans for a New Numerical Forecast System

Plans are underway for the design and construction of a new PE prediction system which will be suitable for operational forecasting and will also serve as a research tool. The prediction model will incorporate the research results that presently appear most promising. In particular, the model will contain high-spatial resolution, fourth-order spatial accuracy, and semi-implicit time differencing. These ingredients will reduce truncation errors at relatively small computer requirements. It is planned that the PE model will contain sufficient flexibility to permit ease in carrying out carefully designed experiments.

(Development Division Staff)

M. Stochastic Dynamic Prediction

1. Higher Order Moment Equations

The stochastic dynamic equations are applicable to a wide variety of scientific problems. How soon these equations can be applied to operational numerical weather prediction problems depends upon the degree of approximation one can and/or is willing to accept. The answer of how to approximate the stochastic equation set is dependent upon the question of "closure."

Until recently, the derivation of the stochastic equations for third moments and higher was a tedious algebraic task. However, we have succeeded in formulating this derivation in terms of a recurrence relation solvable on a computer. From the results of the computer solution and by using mathematical induction, we have been able to show that the higher-order moments are given by an explicit formula. Another formula has been found for the set corresponding to the deterministic equation which contains nonlinear cubic terms. These equations, comments on how they might be solved, and a discussion of potential application will be included in a forthcoming publication.

2. Use of Artificial Viscosities

The stochastic dynamic equations deal with the predictability of various scales and types of atmospheric motion in an explicit manner. The variances of each dependent variable is a predicted quantity which evolves in time according to the dynamic situation. Not only can the effects of the uncertainties in the initial conditions be assessed, but also the uncertainties associated with "parameterizing" the external physical forces in a numerical model.

With the two-fold purpose of checking the efficiency of an artificial viscosity as proposed by Leith[4] and of assessing the effect on predictability due to the computational truncation in space, the following experiment was performed. A spectral model (15 wavenumbers in the x-direction and 2 modes in the y-direction) solving the vorticity equation

$$\frac{\partial \nabla^2 \psi}{\partial t} = - J(\psi, \nabla^2 \psi)$$

was integrated quite accurately in time (using a 4th order Kutta-Simpson scheme). Since there is no aliasing in a spectral model, the kinetic energy in this system was conserved. However, there is a buildup of energy near the wavenumber cutoff (the last resolvable wavenumber k_*) because of the cascade of energy and enstrophy (one-half mean squared vorticity). The artificial viscosity used to control this buildup appears in the above equation as the additional term

$$- \beta(\eta)^{1/3} (k/k_*)^2$$

where β is a nondimensional number, η is the enstrophy cascade rate, and k is wavenumber.

The results were very good for this model and suggest that its inclusion in more advanced models would be beneficial. Treating the term

$$- \beta(\eta)^{1/3}$$

as stochastic with an appropriately large amount of uncertainty leads to a decrease in predictability values of about a day (from those values due to other sources of uncertainty) for the 5-7 wavenumber range. The amount of decrease is progressively less for the smaller scale of waves.

3. Controlling Gravity Waves

A low resolution spectral model, capable of isolating answers to various questions concerning initialization and subsequent gravity wave control measures, has been developed. Various deterministic and stochastic devices will be tested.

(R. Fleming)

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[4]Leith, Cecil E., "Numerical Simulation of Turbulent Flow," Properties of Matter Under Unusual Conditions, John Wiley & Sons, Inc., New York, N.Y., 1969, pp. 267-271.

N. Upper Air Branch (UAB)

1. Analysis of Stratospheric Data

a. Applications of satellite radiance data

Radiances measured by the Satellite Infrared Spectrometer (SIRS) have been used to depict stratospheric temperature changes in both Northern and Southern Hemispheres during autumn transition periods. A paper on this topic, "Stratospheric Temperature Variations in Autumn--Northern and Southern Hemispheres Compared," by McInturff of the NMC and Fritz of the National Environmental Satellite Service (NESS), will be published in the January 1972 Monthly Weather Review.

(McInturff)

Investigations have been made on the relations between radiances from SIRS and the Selective Chopper Radiometer (SCR), and the temperature at discrete altitudes. Preliminary results indicate that upper stratospheric heights can be derived directly from measured radiances and lower boundary heights, with acceptably small error.

(Quiroz and Gelman)

b. Empirical radiation corrections

The calculation of mean monthly day-night temperature and height differences for stratospheric levels has been performed for all reporting stations during the period from August to November 1971. This continuation of past studies has provided additional information, including recognition of reduced variability in reports from stations using the Japanese instruments.

(Finger, McInturff, and Johnson)

c. Comparison of SIRS data with radiosonde data

A comprehensive effort is underway to determine the compatibility of SIRS-B retrievals with radiosonde data. Preliminary results indicate that during many periods of the year, SIRS height- and temperature-retrievals for the stratosphere can be used with confidence. However, during periods of winter stratospheric warming and at other times when large-scale changes take place in the high stratosphere, retrievals have been much less reliable.

(Johnson, McInturff, Miller, and Gelman)

d. Improved first guess

A statistical-regression technique for obtaining a first-guess temperature profile at high stratospheric levels has been developed for use in the SIRS-retrieval process. Need for this technique was indicated by the poor stratospheric retrievals obtained during the most recent stratospheric warming episode. Using simulated data, the regression technique improved the first guess at stratospheric levels to such an extent that retrieved temperature profiles at tropospheric as well as stratospheric levels were significantly improved. A paper describing this technique, "A Regression Technique for Determining Temperature Profiles in the Upper Stratosphere From Satellite-Measured Radiances," by Gelman, Miller, and Woolf, has been submitted to the Monthly Weather Review for publication. An adaptation of this method, in cooperation with Smith and Woolf of the NESS, was incorporated into operational retrievals for November 3, 1971.

(Gelman and Miller)

e. Conversion of stratospheric synoptic analysis program to the CDC 6600 computer

Coding of the multilevel preprocessor and analysis programs for levels above 100 millibars have been completed. The programs are being tested, and output routines are being prepared by the Data Automation Division, NMC.

(Johnson)

f. Hemispheric temperature analysis

In response to a request from the Meteorological Satellite Laboratory, NESS, a temperature-analysis program for 14 levels has been modified from existing programs. This new program will provide first-guess information for reduction of Vertical Temperature Profile Radiometer (VTPR) soundings.

(Johnson)

2. Research on Stratospheric Circulation

a. Stratospheric warming

An extensive study of the stratospheric warming during the winter of 1969-70 has indicated that a major impetus for this event is the transfer of eddy kinetic energy from the troposphere to the stratosphere. This energy flux is associated with increased baroclinic activity in the troposphere. The actual cause of the increase in energy transfers and their relation to the blocking phenomenon are being investigated.

(Miller, Brown, Campana, and Johnson)

b. Energetics

Preparation of summaries of various terms in the equations for energy and momentum budgets has continued for the warming period from December 1969 to January 1970 that is under study.

(Miller and Johnson)

c. Accuracy of high-level temperatures

Data obtained at various rocketsonde sites, using radiosondes, rocketsondes, and satellites, are being analyzed.

(Miller, Finger, and Johnson)

d. Planning for meteorological support of supersonic transport (SST) operations

Forecasting requirements for the stratosphere are being investigated.

(Finger and McInturff)

e. SIRS radiance-data interpretation

The development of a method for determining the amplitude and altitude of stratospheric warmings from observed radiances has been followed by work directed toward defining the spatial and time scales of warm air anomalies, with special attention being given to events that occurred during the winters of 1969-70 and 1970-71.

(Quiroz)

f. Verification of critical-layer theory

Various theoretical studies have suggested that the initiation of a stratospheric-warming episode is linked to the development of a critical surface in the stratosphere. Momentum and heat budgets prepared during various warming episodes (see subsection c. above) are being studied to determine if the phenomena predicted through use of these theories do indeed occur.

(Johnson)

g. Investigations of the quasi-biennial oscillation

Autocorrelation techniques have been employed to investigate changes in the quasi-biennial oscillation of the equatorial stratosphere. Analytic relations between phase-speeds and periods of the temperature- and wind-components have been deduced and compared with actual observations. A paper on the subject, "A Note on Variations in the 'Quasi-Biennial' Oscillation," by McInturff and Miller, has been submitted to the Monthly Weather Review.

(McInturff and Miller)

3. Quality Control

a. Quality control working group (QCWG)

The NMC member of the QCWG has been selected as chairman for an indefinite period. The group continues to work on a variety of problems primarily associated with the acquisition and use of operational data at the NMC. Routine activity reports are provided to the various Deputy Directors of the National Weather Service (NWS) offices and the NMC.

b. Marine data

Daily information concerning the availability and quality of upper air data from ships is provided to the Atlantic and Pacific Marine Supervisors. This information is compared with original data from the ships, and deficiencies are identified, investigated, and resolved. In addition, a joint Office of Meteorological Operations (OMO)/NMC effort has been undertaken to improve the acquisition of surface data from marine sources. This project to improve surface data from ships was submitted by the NMC through NWS and NOAA to the Department of Commerce and was accepted as a Manager's Effectiveness Measurement Program. At OMO's request, the NMC agreed to transfer management of the program to Data Acquisition Division (DATAC), with NMC retaining responsibility for technical matters.

c. Statistical summaries and their application

An automated program has been developed which computes monthly summaries of the frequency with which radiosonde observations and pilot-balloon data are being registered within the 2+50, 3+25, 10+00, and 13+00 operational deadlines. The output is being distributed to field units for their review.

d. Rocketsonde data

The United States and the U.S.S.R. have agreed to exchange meteorological rocket data on a limited scale for special inter-hemispheric stratosphere and mesosphere studies. On a reimbursable basis, NMC will perform the analyses, studies, and research for the United States. Additionally, UAB is coordinating the international exchange of data for operational use and the follow-on exchange of detailed data for research applications. The program is expected to be underway early in 1972.

e. Stratospheric studies

An investigation is underway to check the accuracy of data and objective analyses at the stratospheric levels. Manual analyses of the 100-, 50-, 30-, and 10-millibar levels will be compared with the matching machine products. Significant differences in the results of the two methods of analyses will be researched to determine the causes. Data that repeatedly fail to fit normal analysis patterns will be closely examined for systematic errors.

f. Composite moisture index (CMI) charts

A study was performed to determine the reasons for frequent and extensive data losses on the CMI charts (four panels--CMI, stability index, mean relative humidity, and freezing levels). The major cause was a conflict between the time data were received and the schedule set for processing them. To rectify the problem, the Development Division reprogrammed the computations for processing on the CDC 6600 computer instead of the International Business Machines (IBM) 7094. This rectification afforded an additional 15 to 20 minutes for data to be received before processing; initial results indicate that the major part of the problem is solved.

g. Deficiencies of NWS operational radiosonde reports

A statistical survey is underway to identify the probability and frequency of occurrence of deficiencies in NWS operational radiosonde data received by the NMC. Results of this survey are being distributed for use within NWS.

h. Comparison with the National Climatic Center (NCC) statistics

Quarterly, the NCC of the Environmental Data Service publishes the percentage of observations reaching 100, 50, 30, and 10 millibars for each NWS radiosonde unit. The NCC summary for the period from July to September 1971 will be compared with the percentage of 100-, 50-, 30-, and 10-millibar data in final automatic data processing (ADP) run by the NMC for the same period. Results will be reported.

i. Day and night moisture differences

A new research study is being formulated to investigate the day and night differences of moisture at discrete troposphere levels. This study will examine the differences with respect to various instrument types in use throughout the world. Monthly means of day and night differences by station and instrument type and with respect to solar elevation angles will be computed to determine radiation effects on humidity elements.

(Thomas)

IV. EXTENDED FORECAST DIVISION

A. Thermodynamic Model for Long-Range Numerical Weather and Ocean-Temperature Predictions

The thermodynamic model continues to be run twice a month on a real-time basis for possible use in preparation of the official forecast; a discussion of its performance is included in the postmortem of the 30-day outlook.

Highlights of the research activities for the Division during the 6-month period of this report follow:

1. Preliminary steps were taken toward adapting the thermodynamic model to seasonal forecasting. In these experiments based on data for the autumn of 1971, the model was iterated forward 3 months using 30-day (backward) time steps. Results suggest further changes are needed in the procedure.

2. New options for advection of heat by the mean wind are now being tested with the operational model. These options will be evaluated for the period from January to December 1971.

3. Systematic comparisons of observed ocean temperatures (the Fleet Numerical Weather Central (FNWC) at Monterey, Calif., and Extended Forecast Division data) were continued. The modified FNWC data, employing a correction factor, continue to show good agreement with the Division data.

(Adem and Bostleman)

B. Evaluation and Adaptation of Extended-Range Numerical Predictions

1. A verification system for nationwide contour forecasts of precipitation probability has been designed, coded, and used experimentally. The system calculates the Brier Scores, the skill scores based

on them, and the correlation coefficients between observed and forecast contours of departures from normal probabilities. It also provides graphs and tables to help the forecasters diagnose the nature of their errors and to locate the errors of the objective guidance. An intermittent but continuing series of practice forecasts began in August 1970.

(Gilman and Jones)

C. Vertically Integrated Primitive Equation (PE) Model

A vertically integrated PE model is being designed for application to the extended range. The integration, with respect to the vertical, introduces eddy and boundary terms. The necessary parameterization of the vertical eddies is investigated, using normal and daily values of the meteorological variables. The use of normals allows the determination of one parameter, but a time series of daily data permits more degrees of freedom. The best parameterization must be determined experimentally.

The initialization procedure, which was found to be suitable for a version without topography, does not seem to work when topography is included. Efforts are being made to remove this difficulty, with a view to the future when heating will be incorporated. The problems with the procedure stem from the use of pressure-scaled variables, the need for some reasonable divergence of the initial winds, and the requirement for a realistic specification of the divergence tendency.

Data accumulation for parameterization of the vertical eddies continues, and diabatic heating in crude form is being tested.

(Sela)

D. Objective Prediction of Sea-Surface Temperature

Initial experiments in the monthly prediction of sea-surface temperature and sea-level pressure over the North Pacific Ocean, based on the screening-regression method, and the monthly lags between Pacific sea temperature and U.S. air temperature are summarized in a report by Namais and Born, "Empirical Experiments in Large-Scale and Long-Period Air-Sea Interactions." The work on the report was done at Scripps Institute of Oceanography and will be published as a Scripps Research and Development report.

(Namais)

E. Computer Applications Section Activities

1. Extended Forecast Daily Guidance System

a. All programs of the system are being converted from the IBM 7094 to the CDC 6600 computer. Target date for completion of this conversion is the spring of 1972.

2. Long-Range Forecast Programs

a. All programs are being revised to use the permanent files of the CDC 6600 computer as a primary data source.

3. Permanent File Data Bank

a. An expanded 36-day historical "data bank" of both observed and forecast data, stored on permanent disk files, has been created to accomplish the following functions:

(1) Provide access to data for the AHXN (thickness analysis) transmission (pentad means of 500-millibar height, 5/10 thickness, and sea-level pressure).

(2) Provide data for extended and long-range forecast guidance programs other than current analyses and forecasts.

(3) Provide data for monthly climatological summaries.

(4) Provide data for all verification and archival requirements.

(5) Provide data for the routine computation and evaluation of mean errors over a variety of time-averaged periods.

(6) Provide data for interagency distribution such as the weekly collections for the Bonneville Power Administration, the Naval Oceanographic Laboratory, and the Department of Agriculture.

b. An office note is being prepared to describe in detail the contents and use of the 36-day historical files.

4. Local Archived Data

Tapes of the 24-year history of daily sea-level pressure, 700-millibar height, and 700-millibar temperature have been placed in the NOAA Computer Division library. A series of Fortran (and Fortran Extended) subroutines has been written to perform tasks such as to read, write, pack, unpack, and update, replacing the IBM 1401 data processors formerly used to maintain and to retrieve these data.

(Gelhard, Hiland, Jones, and Durdall)

V. DATA AUTOMATION DIVISION

A. Statistical Techniques and Analysis Branch (STAB)

1. Objective Analysis

a. The analysis programs discussed in the preceding NWP Activities, NMC, First Half 1971 report (see IV.A.1.b.) were implemented on the CDC 6600 computer during the reporting period. The package for the Limited-Area Fine-Mesh Model (LFM) was started on September 29. The package for the coarse-mesh Primitive Equation (PE) model has served as backup and was additionally implemented for the 1200Z FINAL (Final Analysis) (10+00) run beginning on December 15. The necessary analyses for the coarse-mesh RADAT (Radar Data) (1+30) run were also started on December 15. An additional version of the fine-mesh analysis, intended to meet the facsimile requirements for the 1:20 million-scale North American area (850, 700, and 500 millibars), was initiated on November 2. Because the backup version will ultimately replace the operational IBM 7094 version, tests are underway to examine whether significant forecast differences result from the two analysis packages.

(McDonell, Newell, Zbar, Desmarais, and Costello)

b. Some modifications are underway in the upper air analysis codes to include the use of off-level and off-time weighting for aircraft observations so as to approximate more nearly the four-dimensional analysis schemes. It also has been found that the treatment of the aircraft observations at the 250-millibar level tends to result in unrealistic vertical stabilities in the 300-, 250-, and 200-millibar layers. Steps are being taken to control this situation. To monitor the availability of data for the different analyses, a special file has been created to log the number and type of reports. An example of this file is shown in table 1 which gives the averages for a recent 10-week period for LFM (2+00) runs (0000Z and 1200Z).

Table 1. Number and type of reports

Types	Millibar levels								
	850	700	500	400	300	250	200	150	100
Land	111	105	103	74	105*	17**	73	71	69
Ship	4	4	4	2	4**	1**	2	1	1
Aircraft	1	2	6	6	38	60	71	23	0
Total	116	111	113	82	147*	78**	146	95	70

*Includes buildups from 700- and 500-mb heights when the 300-mb height is missing.

**Shows low receipt because the 250-mb level was not sent in Part A of the radiosonde transmission during this survey.

(Zbar)

c. Experiments with sea-level pressure analyses have been made to assess the effects of using the surface wind reports from ships in the fine-mesh analysis code. These experiments have led to the following treatment of these reports:

(1) Wind reports are used from ships located poleward of latitude 20^{O}N.

(2) Wind reports are first tested for gross errors by comparison with the geostrophic wind computed from the partially analyzed sea-level pressure field.

(3) Wind corrections are used on scans 3 and 4 with a weight of 0.1 relative to a weight of 1.0 given to corrections caused by pressure only.

(Newell)

d. Results of some recent sea-level pressure analyses have indicated that the analysis procedure may lead to grid-point values which do not seem to agree with nearby reported values. Such a result is obviously not desirable. The situation which causes difficulty is one in which the data influencing a grid point are clustered in one direction away from that grid point. For example, a grid-point value may change considerably more than the largest correction as the result of a single report. A new analysis algorithm is being tested to determine if these troublesome situations can be improved. Essentially, the algorithm replaces the guess value at a grid point with a weighted average of the guess value and of each influencing reported value. A feature of this technique is that the grid-point value is adjusted toward the reported value and not away from it.

(Newell)

e. The current LFM moisture-analysis program provides mean relative humidity (RH) values for the boundary and the two lower tropospheric sigma layers; and in the absence of radiosonde data to calculate RH, the program uses inferred RH from surface synoptic reports based on cloud cover, present weather, and surface humidity. The inferred RH values are based on a limited data sample. To provide better relations, the 0000Z and 1200Z surface reports and calculated RHs from corresponding radiosonde reports have been collected since mid-August 1971. Various frequency distribution summaries are being studied.

(Desmarais)

f. The tropical analysis program is being modified to accept the new data formats on the CDC 6600 computer systems. The resulting program will perform wind and temperature analyses for six levels--850, 700, 500, 300, 250, and 200 millibars. Using these wind analyses, an option permits a mean-wind guess field for the 1000- to 100-millibar layer to be calculated. Layer mean wind also may be computed for all observations in the entire tropical analysis region. To monitor the analyses, a display package has been devised which plots observations, contours the windspeeds, and draws streamlines on a Mercator map. (The streamline code was developed by the National Hurricane Center (NHC), the others by the NMC).

(Irwin)

g. On an experimental basis, the NHC's relocatable fine-mesh analysis procedure (developed by M. Zimmer of the NHC) has been linked with the NMC tropical analysis, and several analyses and forecasts (using Dr. F. Sanders' barotropic model[5]) have been generated.

(Irwin)

2. Updating Asynoptic Reports

Additional tests have been made to evaluate methods for updating asynoptic reports to synoptic time for possible use in operational analysis programs. The Tendency Method, described in the preceding NWP Activities, NMC, First Half 1971 report (see IV.A.2.), was used to update 12-hour-old temperature reports with 12-hour forecast-temperature changes (forecast temperature minus analyzed temperature) from the PE model. The updated temperature values were then verified against the NMC operational-temperature analyses. The results are shown in table 2.

Table 2. Average temperature root-mean-square errors in degrees C for 10 cases.

Method	Millibar level		
	850	500	200
12-hr PE temperature-forecast verification	2.0	1.4	2.1
12-hr persistence of operational-temperature analysis	2.9	2.5	3.1
12-hr tendency-method temperature-update verification	2.3	1.7	2.3

[5]Sanders, Frederick and Robert W. Burpee: "Experiments in Barotropic Hurricane Track Forecasting." J. Appl. Met., 7:4, pp. 313-323, June 1968.

The PE model does not directly use constant pressure-level analyzed heights and temperatures as initial forecast conditions, but instead used initialized fields in sigma coordinates. Usually, the differences between analyzed height and temperature fields and those obtained by means of initialization procedures are small, but as shown in table 3, the temperature and height errors introduced by initialization are of the same order as those for temperature forecasts and updates. Accordingly, the test cases were rerun with the Tendency Method, using the difference between the 12-hour PE forecast and the initialized fields as the 12-hour tendencies. The results as shown in table 3 indicate a slight improvement for 12-hour temperature updates, when the analyzed temperatures are used to determine the 12-hour temperature tendency, and are somewhat inconclusive for 12-hour height updates. A summary report for all test cases is being compiled.

(Desmarais)

Table 3. Average height and temperature root-mean-square errors (RMSE) for 10 cases

Method	Height RMSE in meters			Temperature RMSE in degrees C		
	850	500	200	850	500	200
Initialized minus analyzed fields	10.1	6.4	12.6	2.4	.8	1.6
12-hr tendency update (forecast minus analyzed)	18.2	27.2	44.0	2.3	1.7	2.3
12-hr tendency update (forecast minus initialized)	21.6	27.1	41.2	2.6	1.9	2.5

3. Machine-Processed Observations

a. Routine archiving of surface reports for 0000Z, 0600Z, 1200Z, and 1800Z was begun in December 1971. A program to log and to summarize the receipt of data from surface land stations and selected ships was begun during the reporting period.

(J. Fleming)

b. To provide upper air data in the proper format for the runs made on the CDC 6600 computer system, programs to dump data from the IBM 360 system were implemented. The remaining problems under study are the handling of reconnaissance reports, the removal of duplicate aircraft reports and the processing of moving ships.

(Webber)

c. Both surface and upper air dumping programs are being modified to accept card input of bogus data.

(J. Fleming and Webber)

d. The switchover on the IBM 360 computer system from the 2311 disk packs to the new 660 disk packs required program changes in many of the programs which process observations on the 360 system. Additional modifications are still needed in some programs to utilize the new disk packs efficiently.

(Byle, Fleming, and Webber)

e. The upper air data-receipt summary program has been modified to include an indication of how often a station is received even though the information has not been complete enough to compile a report to count. This change should be helpful in interpreting other aspects of the summaries; it will point out how often reports are received with some sort of discrepancy or how often reports are not sending information the dictionary is flagged to expect.

(Costello)

f. Work underway is near completion on the preanalysis upper air data processor. This work includes the following items:

(1) A routine to calculate a 300-millibar height using the 700- and 500-millibar heights and the forecast stability for the 700-, 500-, 300-millibar layer. Because the 300-millibar level is the key analysis level, it is important that this routine be done, particularly for the RADAT (1+30) run.

(2) A routine to create a file consisting of current and 12-hour-old observations. The merged file makes available the most current report on hand for use by the tropical analysis program.

(3) A routine to perform a hydrostatic check of the reported heights and temperatures and to set appropriate flags on the tested parameters for interrogation by the analysis programs.

(4) A routine, in the near future, to load the observational data into the CDC 6600 computer system as a set of files (as opposed to a single file as was the situation from the IBM 7094 computer system). This multifiling of the reports requires that the pre-analysis processor examine each of these files to generate its single output for analysis. The purpose for multifiling is greater flexibility in loading the different types of observations.

(Costello)

4. Support Programs

a. A program has been written to compute relative humidity and precipitable water for the surface to 850-millibar, 700- to 500-millibar, and surface to 500-millibar layers from radiosonde reports. In addition, the heights of up to five (possible) freezing levels are determined from the temperature sounding. This package is being used for the four-panel facsimile (FAX) charts (FAX N24 and N70). Specifics will be included in the revision to the Forecaster's Handbook No. 1--Facsimile Products.

(Desmarais)

b. Considerable programming effort was provided to assemble the complete LFM package which became operational on September 29, 1971. This support involved basic operational job-setup procedures, permanent file code-updating procedures, recovery procedures, coordination, and debugging. In addition, an extended core storage (ECS) version of the LFM Initialization (LFMINI) was completed and included in the operational LFM package. This version reduces central memory storage requirements from about 312,000 (octal) to 144,000 (octal) locations in the CDC 6600 computer. Some programming support was also provided to enable tests of the Brown-Campana (see II.A.) wind initialization scheme for the LFM forecast code. A diagnostic package has been included in the LFM sequence to provide information on the vertical consistencies of the fine-mesh analyzed heights and temperatures.

(Desmarais)

c. A subroutine was written to compare the date and time of a permanent file against the local clock and to note for the console operator's attention at the console those instances when the permanent file being used violates the established time limits for the NMC's 0000Z and 1200Z cycle operations.

(Irwin)

d. A program was written to provide dumps of the hourly surface observations six times per day. Each dump will consist of four sets of hourly surface observations for input to the CDC 6600 computer system.

(Byle)

e. Programs were written to process the sea-surface temperature analyses received from Monterey and to produce a tape for input to the CDC 6600 computer system.

(Byle)

B. Programming Branch

1. Program Conversion

Some work still remains in the conversion of the NMC's operational programs from the IBM 7094/II computer to the CDC 6600 computer. All programs should be completed in time for the scheduled release of the IBM 7094 early in the next reporting period.

2. CDC 6600 Computer Operations

a. The LFM forecast and associated programs were made operational on September 29, 1971.

b. The RADAT package (which is based on data received 1½ hours after observation time), through the balance equation, is being run on the CDC 6600 in parallel with the IBM 7094/II package to monitor its correctness.

c. The FINAL package (which is based on data received 10 hours after observation time), through the tropospheric analyses, is also being run on the CDC 6600 in parallel with the IBM 7094/II package to monitor its correctness.

3. Computer Graphics System

a. Programming for the LFM output for facsimile in four-panel form was completed during this period. The LFM four-panel chart contains: (1) 500-millibar heights and vorticity, (2) relative humidity, (3) sea level pressure and 1000- to 500-millibar thickness, and (4) precipitation and vertical velocity. Each panel covers the geographic area of the United States and southern Canada for 12- and 24-hour forecast periods.

b. Routine changes were made in both the LFM and PE facsimile codes. This work included preparation of new map backgrounds.

c. Display programs for the CDC 6600 computer, which will replace the IBM 7094/II curve follower programs, are nearly complete and will go into operational test status in January 1972.

d. Data plotting subroutines were developed during this reporting period. As a first application, they are being used in a set of 250-millibar tropical analysis charts.

4. Alaska Transmissions (FOUS 9)

The transmission to Alaska of grid-point winds and 6-hourly precipitation amounts for 24- and 36-hour forecasts began in September 1971. Forty-eight-hour forecast data will be added to the transmission early in 1972.

C. Information Processing Branch (IPB)

1. In early July 1971, an operational program was updated which enables the Automated Analysis Branch of the Analysis and Forecast Division, NMC, to access rejected upper air reports, to correct them if possible, and to update the data base through the use of a cathode ray tube (CRT). When time permits, these changes are later reflected in the data dumps transmitted to the forecasting computers and in the encoded upper air data that are generated and transmitted to the field.

2. Also early in July, the two bulletin headings, FD and WBC, were split into three equally sized bulletins and relabelled as FDUS 1, 2, and 3 KWBC. (FDUS 1, 2, and 3 are U.S. wind and temperature forecasts up to 39,000 ft.) At the same time, the Air Transport Association (ATA) transmissions were expanded to include the low-level bulletin heading FHPN3 (wind and temperature forecasts for 850 , 700 , and 500 millibars in the eastern North Pacific).

3. Late in July, the input data base was changed from the IBM 7094/II computer to the IBM 360 computer, utilizing an upper air processor code running on the IBM 360 facsimile-oriented computer. Dumping and encoding of data will now come from the IBM 360. Coincident with this change, the transmission code was altered to generate international bulletins from the USXX and ULXX headings to the US, UL, UK, and UG bulletin headings with a fixed station format. The label "NILS" is now inserted where stations are missing. (This procedure had been in effect since early July. The Denver, Colo., switch involves a 2400-baud bisynchronous line to the Bureau of Reclamation in Denver.)

4. Early in August, United Airlines became the 12th member of the ATA polling list.

5. At the end of August, the Systems Recording Edit and Print (SREP) program was added to aid IBM customer engineers in diagnosing a long-existing problem with the Branch's 2908 telecommunication box. This fault had been causing about 10 to 20 machine checks a day. The problem was finally corrected.

6. In September, the LFM model became operational which allows earlier dumps (2 hours after data collection time) and earlier transmissions of international bulletins. Also at that time, a more sophisticated restart procedure on the IBM 360 telecommunication computer was introduced. One of the more important elements of that change was the introduction of a differential cold-start procedure. A normal cold-start results in the loss of all incoming and outgoing data. This differential procedure still requires a cold-start for incoming data but retains the existing queues for output.

7. In late September, the retrieval code (RETX) was modified to allow access from a CRT. A routine was incorporated to allow bulletins to be retrieved by heading (formerly only by sequence number) either from the prime or alternate source. This modification was done to correct the problem of legitimate headings being attached to the wrong data. Also, the RETX now permits a bulletin to be switched to a single destination.

8. In early October, a major change was effected to expand the number of lines that can be accommodated on the IBM 360 telecommunications system from 59 to 88. This change was necessary because of the impending addition of the Federal Aviation Administration (FAA) switch and the addition of two ship-air rescue circuits.

9. In mid-October, two bulletins were added (FSNT4 and FSNT3, 24- and 48-hour North Atlantic surface-pressure forecasts) for transmission to the Scandanavian countries. During the same month, 3-hourly bulletins (SIUS1-3, SICN1, and SICN2) were added to our tables which resulted in the generation of the new bulletins FUNT7-16 (18- and 24-hour upper air wind-temperature forecasts) and FDUS6, and FDUS7 (18- and 24-hour upper air wind-temperature forecasts for the southern United States) for transmission.

10. In early November, disk procedures on both IBM 360 operational computer systems were changed to allow equal access. A preliminary upper air processor to handle selected U.S. stations was adapted to facilitate earlier dumping and encoding. An upper air decoder for data from China was also added.

11. In mid-November, the FAA Weather Message Switching Center (WMSC) at Kansas City, Mo., by means of a 2400-baud bisynchronous full-duplex line became operational. Initially, this operation enabled the Branch to discontinue transmissions into the Service A Data Interchange System (ADIS) network (by sending them to the Kansas City WMSC) and ultimately will allow it to drop the ADIS line completely as the Kansas City WMSC fills in for the Service A breach.

12. Also in mid-November, a new Inktronics printer was put into operation. This device operates at 1,050 words per minute and is currently used to output upper air and aircraft reports to the Automated Analysis Branch. This printer shares one logical line in the IBM 360 computer with three other data sets on a priority basis, with the priorities in descending order as follows:

a. Gander, Newfoundland--a dial-up telephone used twice a day to send 2-minute bursts of upper air wind and temperature data to Canada.

b. Local--a punch unit in the NWS communication room for manually sending transmissions coming from the computer on lines not connected to the computer.

c. ATA--a polled network of 12 airlines receiving 1 hour's worth of upper air wind and temperature data twice a day.

d. Inktronics--last on the priority list.

13. Early in December, smaller disk drives were replaced with larger capacity disk drives, necessitating several program changes.

14. In late December, a Data Recall 65K (65,000-byte) memory was added to the IBM 360/30 FAX computer in preparation for a change to seven facsimile lines in January 1972.

15. During this reporting period, the directory of all our incoming and outgoing bulletins was changed from a tape to a disk operation.

The major effort is to prepare the NMC for the complete changeover from the IBM 7094 computer to the CDC 6600 computer. At that time, programming changes to handle seven FAX lines instead of three and to handle two lines of packed-digital FAX will go into effect.

Also, programs are being written to handle the new Varian computer that is to be installed at Miami, Fla. The local Interdata computer was modified to connect directly to the IBM 360/30 computer instead of indirectly through the Digital Facsimile Interface (DFI).

D. Operations Branch

1. Several innovations have been instituted which serve as aids to both programmers and operators.

a. Operating techniques were established with regard to the implementation of new programs and program changes.

b. The documentation for computer operations was updated.

c. A program which prints the contents of the operational magnetic tapes was written for use on the IBM 360 computers.

2. Systems activities on the IBM 360 computers included:

a. Normal maintenance of the IBM Disk Operating System (DOS) for both IBM 360 Systems #2 and #3. Maintenance involves tasks such as cataloging jobs, reallocating core, and updating disk packs.

b. Addition of an accounting routine as part of the DOS supervisor to record all jobs. Daily, weekly, or monthly logs of jobs can be requested. Other options are also available.

c. Adjustment for use of four additional Memorex 660 disk drives by both IBM 360 Systems #2 and #3.

d. Conversion of the climatic temperature (CLIMAT TEMP) program from one computer to another.

e. The making of changes to IBM source programs so as to ensure easier and smoother operation for computer operators.

E. Electronic Equipment Branch (EEB)

1. An interface which allows the IBM 360 computer to output directly to the selector channel of the Interdata computer was purchased and installed by the Branch staff. This interface will now provide the capability for transmission on seven facsimile lines simultaneously through the DFI.

2. The Digital Facsimile Interfaces (DFI) are undergoing extensive modifications continuously to improve their performance; that is, a modification was installed that now permits a map to be restarted without causing gaps whenever a facsimile line is discontinued or interrupted.

3. A joint effort between members of the Branch and the Communications Division is underway to install a new unit on one of the DFI channels. This unit will accept, suppress, and transmit digital data at four times the current rate of speed. At the receiving end, another unit will unsuppress the data and convert them to analog signals.

The Alden facsimile receivers in the field will need no modifications to receive the charts. The DFI used for this test will require modification.

4. The curve plotters which still generate a large percentage of the Branch charts were modified in this reporting period to accommodate a 1:40-million charts, thus reducing the workload somewhat.

5. A Varian computer and Statos Five recorder, purchased as a terminal for NHC, is being checked at the NMC. When the software and hardware packages are satisfactorily checked, the terminal will be installed at the NHC and will be driven by the IBM 360 Systems via Interdata at the NMC in Suitland, Md.

6. The responsibility for monitoring the Uninterruptible Power System (UPS) has been assumed by the Branch. Minor maintenance and routine exercise of the generator are performed. Major malfunctions will be serviced by factory personnel.

7. The Branch assisted in the checkout of the high-speed circuit to the FAA WMSC at Kansas City that is now in full operation.

8. Under a reimbursable cost agreement between the NMC and the Navy Fleet Weather Facility at Suitland, the Branch is maintaining 3M tape recorders which are used to record the Automatic Picture Transmission (APT) passes.

VI. NMC COMPARATIVE VERIFICATION SCORES

A. S_1 Scores*; Sea-Level Progs

	24 hr (12Z)		30 hr (00Z & 12Z)		48 hr (12Z)	
	1970	1971	1970	1971	1970	1971
October						
BWFB	50.4	47.5	51.7	52.5	58.8	64.0
PE	-	51.7	54.2†	57.8†	60.4	67.2
LFM	-	47.6	-	-	-	-
IMP(PE)	-	+4.2	+2.5	+5.3	+1.6	+3.2
IMP(LFM)	-	+0.1	-	-	-	-
November						
BWFB	49.9	46.0	50.1	53.0	60.5	63.8
PE	-	48.6	55.1†	60.1†	62.1	72.6
LFM	-	49.5	-	-	-	-
IMP(PE)	-	+2.6	+5.0	+7.1	+1.6	+8.8
IMP(LFM)	-	+3.5	-	-	-	-

B. Threat (T_s) Scores; Precipitation Progs

	12-24 hr FCSTS 1970	12-24 hr FCSTS 1971		24-36 hr FCSTS 1970	24-36 hr FCSTS 1971
			October		
QPFB	47.2	44.9	BWFB	38.0	36.8
PEP	35.6	34.2	PEP	31.0	29.1
LFM	-	38.0‡			
IMP(PE)	+11.6	+10.7	IMP(PE)	+7.0	+7.7
			November		
QPFB	47.8	48.4	BWFB	38.4	39.1
PEP	37.3	36.2	PEP	31.6	32.4
LFM	-	39.0§			
IMP(PE)	+10.5	+12.21	IMP(PE)	+6.8	+6.7

* 2.5 points have been subtracted from the raw score to reduce score to old hand grid.
† 36 hr PE Scores. ‡ For 48 of 62 cases. § For 47 of 60 cases.

BWFD A&FD's Basic Weather Forecast Branch
QPFB A&FD's Quantitative Precipitation Forecast Branch
PEP Primitive Equation Precipitation
IMP(PE) Improvement of man over PE Forecast
IMP(LFM) Improvement of man over LFM Forecast.
S_1 Score See Teweles, S., Jr., and Wobus, H., "Verification of Prognostic Charts," AMS Bulletin, 35(10): 455-463, December 1954.
T_s Score Area correct divided by area forecast plus area observed minus area correct.

VII. FORECAST VERIFICATIONS--MONTHLY MEANS FOR 1971

A. NMC Grid Area (1,977 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 mb																		
Jul.	.71	128	13.1	176	17.6	.75	159	15.2	228	21.0				.75	178	16.7	251	22.7
Sept.	.80	130	13.7	217	20.6	.82	159	15.6	276	24.6				.81	189	17.7	313	26.9
Nov.	.79	168	15.7	264	23.5	.80	206	18.0	329	27.4				.78	244	20.3	366	28.9
300 mb																		
Jul.	.74	118	12.3	173	18.0	.78	145	14.0	222	21.5				.77	164	15.9	248	23.4
Sept.	.83	123	13.0	222	22.1	.85	146	14.7	279	26.1				.83	177	17.1	317	28.6
Nov.	.84	155	14.9	286	26.9	.85	190	17.5	354	31.1				.82	230	20.3	391	32.7
500 mb																		
Jul.	.68	87	8.7	116	11.9	.74	110	9.9	151	14.3	.63	124	11.1	.75	120	11.0	170	15.7
Sept.	.82	87	8.9	150	14.6	.84	105	10.2	192	17.5	.73	131	11.8	.83	124	11.5	218	19.2
Nov.	.82	116	10.6	203	18.8	.84	141	12.5	255	22.0	.74	171	14.3	.82	166	14.3	283	23.3
850 mb																		
Jul.	.64	78	7.9	84	8.4	.63	102	9.2	110	10.3				.67	106	9.6	122	11.1
Sept.	.74	79	8.2	108	10.2	.77	94	9.4	138	12.3				.78	102	9.8	155	13.2
Nov.	.78	102	9.3	146	12.8	.79	121	10.7	180	14.8				.78	133	11.6	197	15.2
1000 mb																		
Jul.	.65	79	12.2	92	10.0	.62	108	9.7	119	12.1				.66	113	10.7	130	12.9
Sept.	.76	82	9.1	121	12.5	.78	98	10.3	153	14.8				.78	110	11.2	169	15.7
Nov.	.77	105	10.4	165	15.7	.80	125	11.9	198	17.5				.79	142	13.3	215	17.9

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 mb																		
Jul.	.81	113	12.1	196	20.4	.79	153	14.5	244	24.3				.78	172	16.7	263	25.2
Sept.	.89	116	12.8	257	25.0	.87	157	15.8	326	30.2				.84	190	18.8	365	32.4
Nov.	.89	135	13.9	329	29.6	.84	197	18.3	396	34.2				.78	248	22.2	432	35.3
300 mb																		
Jul.	.85	106	11.9	208	22.4	.82	146	14.5	253	26.4				.81	167	16.9	275	27.9
Sept.	.89	121	13.7	273	27.6	.88	157	16.7	341	32.9				.86	192	19.9	382	35.5
Nov.	.91	148	15.7	389	36.8	.88	201	19.7	464	42.1				.82	259	24.5	502	43.2
500 mb																		
Jul.	.82	72	7.5	129	13.8	.80	100	9.2	159	16.4	.80	95	9.5	.79	112	10.9	171	17.3
Sept.	.88	81	9.0	174	17.4	.87	107	11.0	220	20.9	.77	138	13.1	.85	126	12.8	246	22.5
Nov.	.90	101	10.6	256	24.1	.87	138	13.2	317	28.3	.79	182	16.2	.82	172	15.9	347	29.3
850 mb																		
Jul.	.78	63	6.5	93	9.6	.75	86	7.5	117	11.7				.74	92	8.8	123	11.8
Sept.	.82	71	7.3	117	11.0	.82	91	8.9	148	13.1				.81	102	10.2	160	13.7
Nov.	.87	80	8.1	166	15.1	.85	100	9.7	201	17.3				.79	124	11.7	211	17.2
1000 mb																		
Jul.	.79	67	7.3	102	10.8	.77	90	8.8	129	13.1				.75	99	10.1	135	13.2
Sept.	.83	79	8.8	135	13.2	.80	101	10.7	168	15.6				.81	116	11.8	183	16.4
Nov.	.86	92	9.8	190	17.8	.85	114	11.6	228	20.2				.80	142	14.1	235	19.9

C. Europe--Area 3 (143 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 mb																		
Jul.	.76	136	13.6	208	20.4	.77	177	16.5	271	24.7				.77	197	18.4	301	26.7
Sept.	.90	128	13.5	295	27.2	.89	165	16.4	378	33.1				.87	203	19.4	434	36.3
Nov.	.88	173	15.8	374	31.0	.87	218	19.7	471	36.6				.85	270	23.0	521	38.6
300 mb																		
Jul.	.80	135	14.5	229	23.8	.81	173	16.8	292	28.2				.80	202	19.6	331	31.1
Sept.	.90	139	14.9	329	31.6	.90	176	17.5	419	38.0				.88	218	21.3	479	42.1
Nov.	.87	187	18.1	438	39.0	.88	247	23.0	541	44.8				.85	304	27.3	587	46.2
500 mb																		
Jul.	.78	99	9.6	157	15.9	.79	126	11.1	202	19.1	.68	150	13.7	.81	142	12.9	233	21.2
Sept.	.89	97	9.9	219	20.5	.89	123	11.9	286	25.0	.78	173	14.7	.87	148	14.2	328	27.9
Nov.	.89	134	12.8	311	27.4	.87	181	16.5	388	31.7	.82	216	18.3	.85	222	19.5	423	33.0
850 mb																		
Jul.	.75	70	6.6	104	9.9	.78	86	7.7	136	12.1				.80	93	8.5	154	13.5
Sept.	.84	75	7.3	138	12.2	.86	91	8.7	180	14.9				.85	108	10.0	206	16.4
Nov.	.85	112	9.7	219	18.7	.83	145	12.4	266	21.3				.80	175	14.5	287	21.8
1000 mb																		
Jul.	.77	67	6.9	108	10.4	.78	88	8.3	139	12.5				.80	96	9.3	157	13.7
Sept.	.84	78	7.7	146	13.3	.86	95	9.1	185	15.7				.84	114	10.8	212	17.3
Nov.	.85	122	10.8	241	21.2	.82	156	13.6	283	23.3				.79	189	16.0	302	23.7

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 mb																		
Jul.	.74	133	13.2	195	18.9	.79	159	15.7	256	23.0				.76	202	18.6	290	25.6
Sept.	.78	120	12.3	194	18.7	.82	140	14.0	244	22.0				.78	182	16.5	279	24.2
Nov.	.82	137	13.5	238	21.2	.81	185	16.6	305	25.3				.81	212	18.5	348	27.6
300 mb																		
Jul.	.70	125	12.1	170	17.4	.78	142	13.6	219	21.0				.78	169	15.8	251	23.3
Sept.	.80	113	11.6	187	19.4	.84	127	13.2	233	22.6				.80	158	15.2	263	24.6
Nov.	.84	134	13.7	253	23.9	.85	168	16.2	324	28.0				.84	198	18.2	368	30.6
500 mb																		
Jul.	.68	87	8.2	112	11.4	.74	104	9.2	144	13.7	.63	121	10.8	.73	122	10.6	166	15.2
Sept.	.79	78	7.8	126	13.2	.83	88	8.8	158	15.4	.64	123	10.9	.80	109	10.0	178	16.8
Nov.	.82	104	9.5	181	17.0	.87	112	10.6	231	19.9	.67	168	13.2	.87	128	11.8	264	21.9
850 mb																		
Jul.	.55	95	10.3	85	8.4	.51	132	13.1	110	10.4				.58	132	12.7	124	11.3
Sept.	.68	86	10.4	99	9.8	.68	107	12.3	123	11.5				.74	103	11.2	136	12.4
Nov.	.71	100	10.8	118	10.1	.73	122	12.2	147	11.9				.75	124	11.8	165	12.6
1000 mb																		
Jul.	.58	95	9.0	94	10.0	.50	134	10.4	123	12.2				.59	135	11.9	134	13.2
Sept.	.75	83	9.0	118	12.4	.75	103	10.1	149	14.8				.77	108	10.8	160	15.4
Nov.	.78	96	9.3	139	12.6	.81	106	10.8	171	14.5				.79	126	11.7	190	15.1

R — Correlation coefficient of forecast and 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 six-layer primitive equation baroclinic forecast model.
PERS — Persistence forecast.
BAROTROPIC — Operational barotropic forecast model.

VIII. MACHINE PERFORMANCE AND UTILIZATION

A. IBM 7094/II

1. 7094/II Profile

a. Released equipment - none

2. Utilization--2,614 hours.

B. IBM System 360/30

1. 360/30 Profile

a. Leased equipment:

3 - Memorex 660-1 Disk Storage Drives	12-71
1 - Memorex 661-1 Disk Storage Control Unit	12-71
1 - IBM 2914-1 Switching Unit	11-71

b. Released equipment:

4 - MAI 2301-1 Disk Storage Drives	12-71
1 - IBM 2911-1 Switching Unit	12-71
1 - IBM 2841-1 Disk Storage Control Unit	12-71

2. Utilization--4,220 hours.

C. IBM System 360/40

1. 360/40 #1 Profile

a. Leased equipment:

2 - Teletypewriter 2101AB Data Speed Printers	9-71
1 - IBM 1443-1 Printer	8-71
2 - IBM 129-3 Printing Card Punches	9-71

b. Released equipment:

1 - IBM 1443-1 Printer	8-71
1 - IBM 026-1 Printing Card Punch	9-71
1 - IBM 029-1 Printing Card Punch	9-71
1 - IBM 129-3 Printing Card Punch	10-71

2. Utilization--4,331 hours.

D. IBM System 360/40

1. 360/40 #2 Profile

a. Leased equipment:

1 - Memorex 660-1 Disk Storage Drive	11-71
1 - IBM 1416-1 Print Chain	11-71

b. Released equipment:

1 - IBM 1416-1 Print Chain	11-71

2. Utilization--3,286 hours.

E. CDC 6600, Computer Division, NOAA

1. CDC 6600 Profile

1 - 6601 Central Processing Unit (CPU)
2 - 6612 Central Processing Units (CPU)
2 - 6613 Consoles
31 - 607 Tapes
6 - 512 Printers
6 - 3555 Printer Controllers
4 - 3423 Magnetic Tape Converters
5 - 405 Card Readers
5 - 3447 Card Reader Converters
3 - 415 Card Punches
3 - 3446 Card Punch Converters
14 - 6681 Data Channel Converters
1 - 3228 Magnetic Tape Converter
5 - 3291 Entry Display Units
6 - 6638 Disk Systems
6 - 10037A/RW Options
4 - 6671 Data Set Multiplexes
6 - 595 Train Cartridges for 512 Printers
7 - 2172 Terminal Cathode Ray Tubes (CRT)
7 - 2222 Terminal Printers
7 - 2242 Terminal Readers
1 - 6635 Extended Core Storage
5 - 10010 Long-Line Driver Modifications
2 - 659 Magnetic Tape Transports (9-track)
1 - 3518 Magnetic Tape Controller
1 - 6846 Modified to 6671
3 - GK122 Channel Switches
1 - GK128 Channel Switch

2. Utilization for NMC work--Central Processing Unit 1,526 hours
Peripheral Processing Unit 3,129 hours.

IX. PERSONNEL CHANGES

Extended Forecast Division

1. Philip F. Clapp, Chief of Research Branch, retired on December 31, 1971.

2. Jerome Namais, Chief, retired December 31, 1971.

Analysis and Forecast Division

1. Jerry M. Davis, Meteorologist, Basic Weather Forecast Branch, transferred to Eastern Region on December 13, 1971.

X. DISTRIBUTION OF PRODUCTS

As of December 31, 1971, the National Meteorological Center (NMC) was originating approximately 639 separate teletypewriter bulletins each day for transmission over National Weather Service, U.S. Navy, U.S. Air Force, and Air Transport Association (ATA) teletypewriter service. In addition, NMC makes the following daily facsimile transmissions:

National Facsimile Network (NAFAX)	95
Aviation Meteorological Facsimile Service (AMFAX)	65
Navy Facsimile Network	17
Air Force Facsimile Network	138
International Facsimile Network (Offenbach, Germany)	51
Russian Facsimile Network	36
Forecast Office Facsimile Network (FOFAX):	
Circuit #10206	56
Circuit #10207	56
Circuit #10208	53
Caribbean Radio	20
Tropical Analysis Network (TROPAN)	25
Suitland-Honolulu Circuit	58

XI. PUBLICATIONS BY NMC PERSONNEL

1. *Fleming, Rex J.: "On Stochastic Dynamic Prediction, I. The Energetics of Uncertainty and the Question of Closure," Monthly Weather Review, Vol. 99, No. 11, Nov. 1971, pp. 851-872.

2. ________________ "On Stochastic Dynamic Prediction: II. Predictability and Utility," Monthly Weather Review, Vol. 99, No. 12, Dec. 1971, pp. 927-938.

3. Gerrity, Joseph P., Jr., and McPherson, Ronald D.: "On an Efficient Scheme for the Numerical Integration of a Primitive-Equation Barotropic Model," Journal of Applied Meteorology, 10:3, pp. 353-363, June 1971.

4. McInturff, R. M., **Lewis, F., and **Greene, D. R., "The Correlation of Tail-Wind Components and Temperature at SST Levels," Final Report, 32 pp.

5. ________________ and Miller, A. J.: "Possible Effects on the Stratosphere of the 1963 Mt. Agung Volcanic Eruption," Journal of the Atmospheric Sciences, 28:7, pp. 1304-1307, Oct. 1971.

6. McPherson, Ronald D.: "Reply" to "Comments on 'A Numerical Study of the Effect of a Coastal Irregularity on the Sea Breeze'," Journal of Applied Meteorology, 10:3, pp. 600-601, June 1971.

7. Miller, Alvin J., and †Schmidlin, Francis J.: "Rocketsonde Repeatability and Stratospheric Variability," Journal of Applied Meteorology, 10:2, pp. 320-327, April 1971.

8. ________________ and Finger, F.: EXAMETNET--The First 5 Years, 1966-1970, June 1971, 52 pp.

9. Pope, Cadesman, Jr., "Tropical Cyclone Eye Re-Formation After a 30-Hour Movement Over the Malagasy Republic," Monthly Weather Review, 99:6, pp. 478-484, June 1971.

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*Air Weather Service, U.S. Air Force

**Staff Member, Techniques Development Laboratory, Systems Development Office, NWS.

†Staff Member, NWS, Wallops Island, Va.

10. Quiroz, Roderick S.: "Comment on Paper by F. Verniani and G. Cevolani, 'The Seasonal Variation of the Atmospheric Temperature near the Mesopause Level: Preliminary Results'," Journal of Geophysical Research, Vol. 76, No. 36, p. 8695, Dec. 20, 1971.

11. ________________ "The Determination of the Amplitude and Altitude of Stratospheric Warmings from Satellite-Measured Radiance Changes," Journal of Applied Meteorology, 10:3, pp. 555-574, June 1971.

12. Sela, J., and ‡Jacobs, S. J.: "Ageostrophic Effects on Baroclinic Instability," Journal of the Atmospheric Sciences, 28:6, pp. 944-953, Sept. 1971.

13. ________________ "Ageostrophic Effects on Gulf Stream Instability," Journal of the Atmospheric Sciences, 28:6, pp. 962-967, Sept. 1971.

14. Staff, Extended Forecast Division: One or more of the six monthly "Weather and Circulation" summaries published in the Monthly Weather Review, 99:7-12, July to December 1971, were prepared by the following authors: Raymond A. Green, L. P. Stark, Julian W. Posey, A. James Wagner, and Robert E. Taubensee.

15. Staff, Upper Air Branch: "Weekly Synoptic Analyses, 5-, 2-, and 0.4-Millibar Surfaces for 1968," NOAA Technical Report NWS 14, 169 pp., May 1971.

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‡Department of Meteorology and Oceanography, the University of Michigan

Technical Memorandum

#50 McPherson, Ronald D., "Recent Research in Numerical Methods at the National Meteorological Center"

Office Notes

#53 Gerrity, J. P., McPherson, R. D., and Polger, P. D., "Requiem for an Integration Procedure"

54 Shuman, F. G., "Resuscitation of an Integration Procedure"

55 Gerrity, J. P., and McPherson, R. D., "Numerical Instability of a Mixed Implicit-Explicit Integration Procedure"

56 Shuman, F. G., "A Suggested Modification of Computational Procedures for Spherical Coordinates"

57 Gerrity, J. P., "Digital Filters for Use in Post-Processing Forecast Fields"

58 Clapp, Phillip F., "Modification of an Empirical Short-Wave Radiation Formula Using Satellite Observations"

59 Stackpole, John D., "Convective Rain in the PEP Model"

60 Gerrity, J. P., and Scolnik, S. H., "Further Properties of the Method of Time Averaging as Applied to Wave Type and Damping Type Equations"

61 Collins, William, "On an Improved Form of the Hydrostatic Equation in Finite Differences"

62 Gerrity, J. P., and Scolnik, S. H., "Some Comments on Robert's Time Filter for Time Integration"

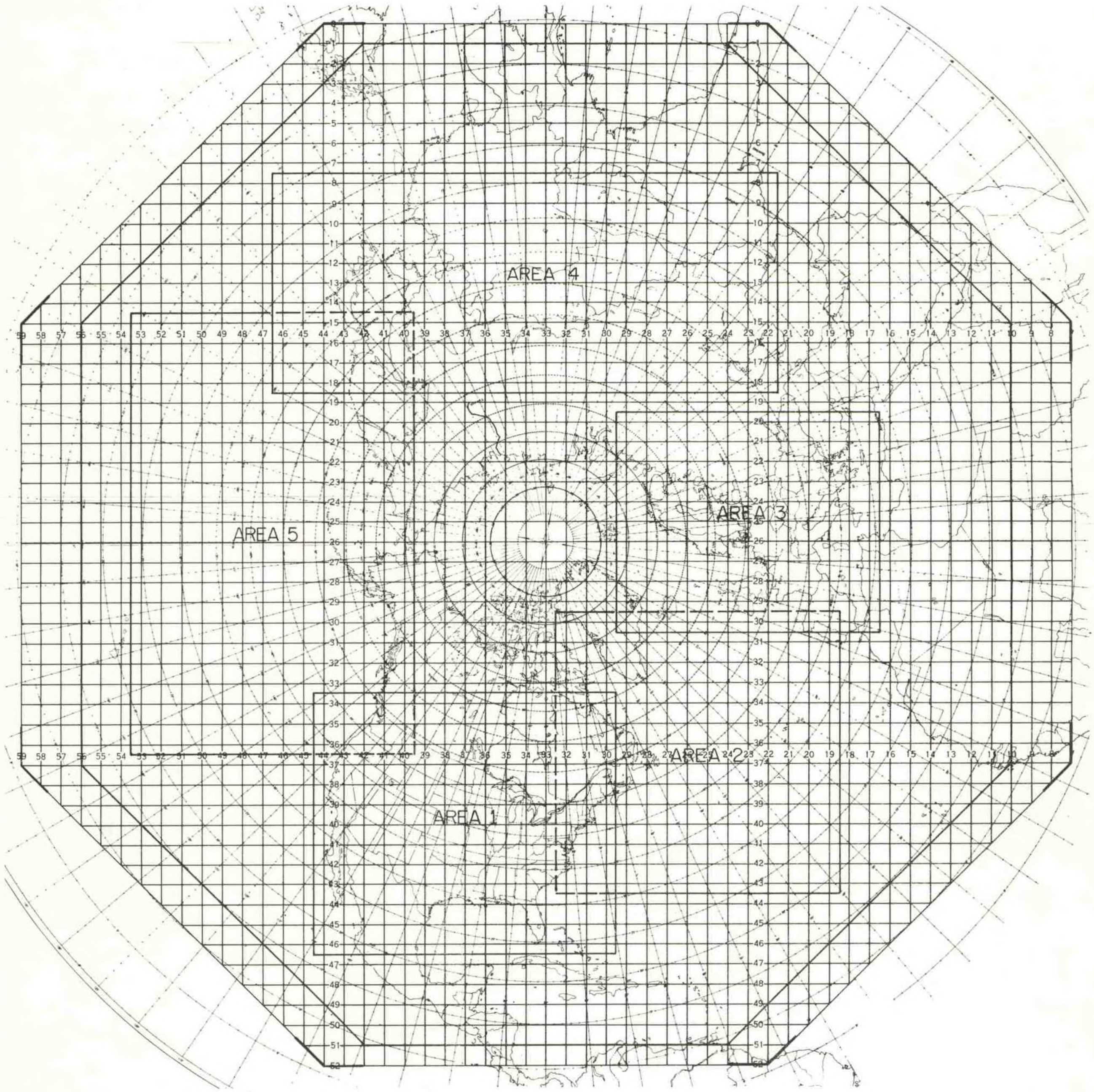
63 Data Automation Division, NMC, "FMARKIV and PEPMERG Data Tapes"

64 McPherson, Ronald D., and Polger Paul D., "The Red Herring Affair: Modified Semi-Implicit Methods Revisited"

65 Gerrity, J. P., and McPherson, R. D., "A Semi-Implicit Integration Scheme for Baroclinic Models"

66 Clapp, Phillip F., "Atlas of Horizontal Eddy Heat Transport in the Atmosphere"

67 Shuman, Frederick G., "Detection and Correction of Errors in Height and Temperature Analyses"



Verification Areas