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Numerical Weather Prediction Activities

National Meteorological Center
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NATIONAL METEOROLOGICAL CENTER

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I. INTRODUCTION

This report summarizes the numerical weather prediction (NWP) activities of the National Meteorological Center (NMC) for the first half of 1972. During that period, the time step of the coarse-mesh[1] six-layer primitive equation (6L PE) model was increased from 10 to 20 minutes, adaptation of the Air Force Global Weather Central (AFGWC) planetary boundary layer (PBL) model to the NMC environment was completed for testing, and operational testing of the hemispheric eight-layer primitive equation (8L HEM) model was begun. Also included in this report are summaries of recent developments in data automation and verification statistics for the 6L PE model.

II. REVISIONS IN OPERATIONAL PROGRAM

A. New Procedures Introduced Into the Limited-Area Fine-Mesh Model

1. The Brown-Campana initialization procedure that was incorporated into the operational coarse-mesh primitive equation model last August was also introduced into the limited-area fine-mesh[2] (LFM) model on March 21, 1972. A complete description of the new procedure may be found in NWS Technical Procedures Bulletin No. 65.

2. On April 18, 1972, a filtering procedure was added to the output section of the LFM in order to improve the appearance and credibility of its facsimile products. Prior to this time, only minimal smoothing had been done in preparing the LFM forecasts for output.

3. The bias of the LFM in overforecasting precipitation during the early winter, and then in underforecasting during the spring, has led to operational changes that adjust the threshold value for the onset of precipitation in the model. The threshold had been set at 95 percent in December 1971 and January 1972, during which time the model was too wet. The value was adjusted to 97 percent on February 2, 1972. A dry bias became apparent in the May verification statistics, therefore the threshold was set to 95 percent on June 5, 1972. The model continued to be dry, and the value was lowered to 90 percent on June 20. With this experience gained during the past year, a seasonal variation of this precipitation threshold value will be incorporated into the LFM.

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[1] 381-km grid distance on polar stereographic projection true at latitude 60°N.
[2] 190.5-km grid distance on polar stereographic projection true at latitude 60°N.

4. On May 31, 1972, the time step on the operational LFM model was increased from 5 to 6 minutes. This change takes advantage of the reduced intensity of large-scale circulation systems during the warmer season. Since these are weaker, the time step can be reduced with little risk of exceeding computational stability criteria. Experimental results with the 6-minute step were insignificantly different from comparable operational runs with the 5-minute step.

B. Summary of Changes to 6L PE Model

1200 GMT January 6, 1972: Input to initialization changed from random-access files rather than magnetic tape (a programming change related to International Business Machines (IBM) 7094 to Control Data Corporation (CDC) 6600 Computer conversion--the model physics remained unchanged).

0000 GMT May 19, 1972: The modified leap-frog differencing system (see Chapter III, Section G below) was incorporated with a 20-minute time step. This goal was reached after a period of time in which experience was gained with a 15-minute time step. A stable configuration has been obtained with the following features:

1. The constant a is set to 0.245 during the first 6 hours of forecast time (see previously cited reference). It is then changed to 0.25 thereafter.

2. A light time smoother is applied to the $\tau-1$, τ, and $\tau+1$ time levels of the momentum field.

3. Horizontal space smoothing on temperature and pressure is removed. Instead, lateral momentum diffusion is incorporated south of 20°N, together with a method which yields a quasi-steady-state condition in these low latitudes near the lateral boundary.

4. Vertical mixing of winds due to wet or dry convective adjustment is deleted--a programming convenience which has led to no apparent diminution of forecast skill.

5. A 2-hour time average is made of the vertical velocity and pressure fields for the display of these forecast products. This modification of the output package was not designed exclusively for the 20-minute time-step modification, but had been planned earlier for implementation in the 10-minute time-step system.

1200 GMT June 21, 1972: Improved method of expanding winds and heights from the octagon into the rectangle was introduced into the initialization procedure. (See Chapter III, Section H below.)

C. Forecast Verification Statistics

The computer program, which has been used to obtain the monthly verification summaries (see Chapter VI of this report), has been converted to another computer and data bank system. In making this conversion, it was discovered that in the calculation of geostrophic wind statistics, both root mean square vector error (RMSVE) and root mean square vector wind (RMSV) values, the map factor, $m = (1 + \sin 60^o)/(1 + \sin \phi)$ in which ϕ is latitude, was inadvertently inverted in the original program.

Beginning with the July 1972 verification summary, correct wind statistics will be published and weighting of grid point values by area will be incorporated. An approximate multiplicative correction factor can be applied to the geostrophic wind statistics which have been published for the time period prior to July 1972. It is

$$N/\sum_{i=1}^{N} (1/m_i^2),$$

where N is the number of grid points in the verification area. Its value for each of the grid areas is given below:

Grid	Area 1	Area 2	Area 3	Area 4	Area 5
1.40	1.33	1.23	1.09	1.31	1.32

A test using June 1972 verification data has shown these correction factors to be reasonable. In the interests of further refinement of these factors, beginning with July 1972 and for each month through June 1973, calculations with the inverted map factor will be made for comparison with the published statistics. At the end of a year (June 1973), the results of these comparisons will be reported.

III. DEVELOPMENT DIVISION

A. Spectral Analysis and Prediction

1. Global Analysis

Twice-daily global analyses have been performed on a routine basis since January 1972. Initially the program was run using a truncation of wave 16 in longitude, five empirical orthogonal functions in the vertical, and 24 Hough functions (of latitude). Resolution has since been increased to wave 20 in longitude and six vertical functions. The analyses produce global heights, winds, and temperatures from 1000 to 50 mb. The program originally accepted only upper-air data but now uses surface observations as well. Modifications are currently being made to produce humidity analyses.

The global analyses are not now being used by other operational programs, but are scheduled to soon replace certain products run at "final" time. They were used for operational support of the Apollo 16 mission forecasts, serving as initial conditions for the three-layer global model (see Section C below). They have also provided analyses for a number of test runs of the new 8L HEM model (see Section B below), and have been used as a first guess for an experimental fine-mesh analysis program of the National Hurricane Center. Currently, continuity is maintained by using persistence as a first guess. This has caused certain undesirable effects, especially in the large data-void regions of the Southern Hemisphere. Systems persist for many days in these regions, as no data are available to change the guess. This problem will be remedied by the introduction of a global forecast into the analysis cycle.

2. Spectral (Global) Forecast Model

Experiments have continued with a global forecast model using Hough functions. Problems with the baroclinic version forced a re-examination of the barotropic code, and several numerical errors were uncovered. The barotropic forecast code now requires about 9 seconds running time for each forecast hour. It appears to be completely stable (a 16-day forecast gave no indication of stability problems) and produces reasonable forecasts. Further experiments with the baroclinic version are planned.

3. Satellite Infrared Spectrometer (SIRS) Data Experiment

An experiment using global SIRS data was performed in April and May in cooperation with National Environmental Satellite Service (NESS). Guess soundings from the global analyses were used to obtain retrievals from SIRS radiance data, and the results were fed back into subsequent analyses. The results were inconclusive as no realistic surface temperature data were available for the Southern Hemisphere and cloud-discrimination was quite uncertain. It can be assumed that the Vertical Temperature Profile Radiometer data, which will become available in the autumn, will give much more satisfactory results as the data will be more plentiful, more accurate, and more complete. (Flattery, Johnson, and Goddard)

B. Hemispheric Eight-Layer Primitive Equation (8L HEM) Model Development

1. Numerical Stability

The use of the triangular form for convolution to interpolate and smooth the tendencies from the grid boxes to the grid columns proved to be an unqualified success, thus resolving all the numerical stability problems alluded to in the previous report. The details are to be found in NMC Office Note 69.

2. Radiation Model

A more complete radiation model, incorporating C. D. Roger's emissivity values (Quarterly Journal of the Royal Meteorological Society, Vol. 93, No. 395, January 1967) for the long-wave flux calculations and incorporating a calculation of surface temperature, via energy equilibrium, was assembled and incorporated into the full model.

3. Testing

With the numerical problems cleared up and the major physics of the model intact, a series of tests (current data forecast to 84 hours) were undertaken as preliminary evaluations. As a result of the continuing test series, a number of changes and alterations have been made.

a. The data extraction from the global analysis method (section A above) was improved, most notably in the manner of using given heights to obtain temperatures at significant levels.

b. Some premature failings of the forecast were cured when the global analysis was extended upward to 50 mb (from 100), thus allowing for a better definition of the tropopause.

c. Smoothing the analyzed tropopause pressure, which is defined by scanning the temperature at each gridpoint seeking the region of minimum lapse rate, contributed significantly to the forecast quality.

d. In the absence of a Northern Hemisphere relative humidity analysis, we have tentatively specified an arbitrary uniform relative humidity. With 50 percent everywhere, the problem of shrinkage of the entire troposphere from excessive cooling remained. By the end of the forecast, however, the rate of cooling had diminished to almost zero. Since by the end of 84 hours a meteorologically reasonable pattern of clear and cloudy sky has developed, this suggests that with an initial analysis of humidity the problem of excessive cooling will cease to exist. This is still an open question, however. Some forecast tests were run with 80 percent initial relative humidity, thus filling the model atmosphere entirely with cloud. The excessive cooling and troposphere shrinkage did not occur; however, latent heat produced overdevelopment in the Tropics and subtropics. (Stackpole)

C. Global (Grid Point) Forecast Models

Several new programs have been designed and completed for use in connection with the global three-layer (3L GLOBAL) and global barotropic forecast models:

1. The vorticity equation is being solved, using winds as data, for the global stream function field on a pressure surface.

2. A form of the balance equation is being solved on a pressure surface for a global correction to the initial height field using winds and heights derived from Hough functions. This correction to the heights ensures better agreement of initial winds and heights and, when applied, significantly reduced the amplitude of the large-scale gravity waves in the global barotropic forecast calculation.

3. The triangular tendency averaging method, mentioned in Section B above, has been included in both the 3L GLOBAL and barotropic forecast models. Stable forecast calculations to 72 hours, using a 15-minute time step, have been made with the 3L GLOBAL model (on a 3.75^{o} latitude-longitude grid). Stable forecast calculations to 55 days using a 30-minute step have been made with the barotropic model (on a 5^{o} latitude-longitude grid).

4. Now being checked-out and tested in various combinations (using, for some of the effects, parameterizations approximately as described by Gadd and Keers in "Surface Exchanges of Sensible and Latent Heat in a 10-level Model Atmosphere", Quarterly Journal of the Royal Meteorological Society, Vol. 96, pp. 297-308, 1970), in the 3L GLOBAL

model are:

a. Three layers of moisture.

b. Latent heat.

c. Precipitation.

d. Short-wave and long-wave radiation with moisture parameterized as clouds.

e. Convective adjustment.

f. Heating of the boundary layer over the oceans.

g. Evaporation into the boundary layer.

h. Surface drag in the boundary layer.

i. Climatological tropopause pressure, zonally averaged and constant in time, used as the top of the model atmosphere.

(Vanderman and Hirano)

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

1. Stability Problems

A combination of circumstances has caused unrealistic wind analyses near the latent boundaries of the LFM grid that have led to model failure in a few instances. Until recently, the LFM obtained its initial winds through use of the balance equation, which depended on a 12-hour 6L PE forecast for boundary values in the balancing procedure. When there were substantial differences between the LFM analyses and these forecasts near LFM lateral boundaries, spurious strong winds were initialized for the model causing subsequent stability problems. The new Brown-Campana initialization procedure, introduced into the operational coarse-mesh model in August 1971 (NWS Technical Procedures Bulletin No. 65), makes use of analyzed rather than balanced winds. Tests of the procedure on the problem cases were made with good results; that is, the model ran satisfactorily to completion. In testing with reruns of LFM cases in which the LFM forecasts had been quite good, the new procedure did not degrade the forecast and, in some cases, resulted in some overall improvements. These tests provided sufficient impetus for adopting the new procedure into the operational LFM on March 21, 1972.

2. Output Smoothing

The rough appearance of the LFM forecast fields was not really apparent until the Varian facsimile display became available just before the operational implementation of the model last September. The only filtering done in the model at that time paralleled that used in the operational coarse-mesh model to destroy the two-grid-interval wave. As a result, some rather distressed-looking charts were transmitted. Their nonmeteorological appearance was at least distracting and in some respects reduced the credibility of the model. The rationale for continuing this sort of output was that forecasters needed some experience with the model in order to evaluate its output for meaningful content in the smaller scale features of the charts. Investigations demonstrated that the poor appearance resulted mostly from a four-grid-interval wave generated as computational noise at the lateral boundaries. Several cosmetic filters that would attack the offending wave without doing violence to meteorologically significant features were designed and tested. The best was put into the operational model on April 18, 1972. Essentially, the height, temperature, and wind component fields continue to have the older two-grid-interval annihilator passed over them and then the fields are passed through the newer filter to reduce the four-grid wave. Derived fields, such as thickness and vorticity, do not receive any further smoothing. The responses of selected Fourier component waves to the combined filters are shown in table 1; those from the older operational filter are shown for comparison.

Table 1.-- Response Characteristics

(Amplitude of Fourier Component Retained)

Component (grid-intervals)	Old Filter (operational)	New LFM Filter (operational)
2	.000	.000
3	.438	.068
4	.750	.375
6	.937	.791
8	.978	.921
12	.995	.982
infinite	1.000	1.000

3. Inflated Pressures

The "pillow" problem in the LFM has been the subject of continuing investigation by NMC staff members. The pillow is defined as the change in average surface pressure over the LFM grid during the course of a forecast. It can be either positive or negative, but most frequently is positive. The effect seems to be distributed more or less uniformly over the grid and seems to be an overstatement of the secular trend in the total mass of the actual atmosphere passing through the LFM area. Examination of surface and upper-air charts has led to a tentative conclusion that the pillow is highly correlated with entrapment of a vigorous midtropospheric system on the time invariant boundaries of the LFM. (Howcroft)

E. A New Numerical Forecast System

The development of a new LFM model based upon the use of the semi-implicit integration method has been chosen as the operational objective for this project. To accelerate progress and to provide flexibility in testing, the initial development will be made using a 27-by-29 array of gridpoints in the horizontal. The vertical structure of the new model will be the same as that used in the operational LFM model. The only changes envisaged in the formulation of the model are those necessitated by the new integration method.

Although it is anticipated that subsequent development will use a greater number of gridpoints, the incorporation of fourth-order accurate approximations for the spatial derivatives appearing in the nonlinear terms of the equations should, in principle, provide the proposed model with numerical accuracy equivalent to that now available in the operational LFM model.

Work on this project to date has involved the derivation of the model equations, the preparation of program specifications, and tests of the linear components of the equations. Some results obtained in the course of this work have been documented.

An analysis of the free gravitational modes admitted by the model was reported in NMC Office Note 74. Certain inconsistencies in the treatment of the dynamical role of water vapor were noted in the Shuman-Hovermale 6L PE model during the derivation of the new model. These were reported in NMC Office Note 71. The solution of the simultaneous system of Helmholtz-type equations that appear in the new model was accelerated by the use of a matrix triangulation scheme discussed in a manuscript by Sela and Scolnik, which has been submitted for review.

It is planned to have the coding of a dry-adiabatic version of the model completed by the end of August. Tests of that version of the model are planned for the fall of this year, in order to examine the treatment of boundary conditions and orography. (Development Div. Staff)

F. Planetary Boundary Layer Model (PBL)

The second phase of the PBL project was completed during this period. Integration of the model on three dissimilar synoptic situations was performed in order to evaluate qualitatively various aspects of the model's performance.

Prior to these experiments, a series of minor modifications were introduced into the model. An adiabatic temperature correction was included in the analysis package to account for the difference between actual and model terrain height. The specification of the radiation part of the surface temperature was modified to take into account the length of day as a function of latitude and season. Also, the scaling procedure for reducing the amplitude of the diurnal temperature wave was modified. The output package now uses the FR80 microfilm recorder and is capable of producing horizontal depictions of any of the dependent variables at any level, including vector wind plots. Time cross-sections at individual grid points are also available. In addition, derived fields such as vorticity, divergence, stability indices, and a long list of air stagnation-related quantities can be produced.

A detailed description of the three components of the PBL package....analysis, prediction, output....has been prepared as NMC Office Note 75.

The three synoptic cases studied indicate that the PBL model is capable of forecasting first-order effects in the boundary layer with sufficient skill to warrant a further period of quantitative testing and evaluation. A number of weaknesses, both in the analysis and prediction, were also noted, suggesting that some further development work is needed. Documentation of these three case studies is being prepared.

It is envisioned that the third phase of the project, the period of objective test and evaluation, will commence during the second half of 1972. (Gerrity, Gross, Jones, McPherson, and Goddard)

G. A Modified Leap-Frog Differencing System

On May 18, 1972, the time-step in the operational six-layer coarse-mesh primitive equation model was changed from 10 minutes to 20 minutes. (See NWP Activities, NMC, Second Half 1971 Report, Chapter III., Section I.) This was accomplished by a modification of the differencing system of the pressure gradient terms in the momentum equation. Consider

$$\frac{\partial \vec{V}}{\partial t} = \ldots - \overline{[\nabla\phi + c_p\theta\nabla\pi]}^{t}$$

where

$$\overline{(\ )}^{t} = a[(\ )^{\tau-1} + (\ )^{\tau-1}] + (1-2a)(\ )^{\tau}$$

and

$$\pi = (p/p_o)^{R/c_p}.$$

Here $\vec{V}$ is the vector wind, ϕ is the geopotential, c_p is specific heat at constant pressure, θ is potential temperature, p is pressure, p_o is 1000 mb, R is the gas constant for air, and τ is the time-step index. When a=0, the system is the leap-frog scheme, which was previously used. When a=0.25, the condition for linear stability (the absence of exponentially amplifying solutions) allows for a time-step twice that for a=0. However, computational modes are allowed to amplify linearly with time. Devices have been incorporated to control these in the forecasts made daily to 48 and 84 hours. A substantial reduction in computer costs has been realized. Complete documentation of this new system is planned. (Shuman, Brown, Campana, and Bedient)

H. New Expansion Technique for the PE Model

The routine analysis procedure at NMC provides values of heights, temperatures, and winds at pressure levels over an octagonal region of a polar stereographic projection of the Northern Hemisphere. Since the operational 6L PE model forecast area is larger than the analysis region, a method must be devised for expanding the initial data into this larger area.

The current method of expansion begins by determining the average value of any variable along the octagon boundary and placing that constant value everywhere outside the analysis region. Then the two regions are meshed by a smoothing technique. Often, non-meteorological features are introduced outside the octagon (such as large height gradients and strong winds). Sometimes these features propagate inward and harm the PE forecast.

The new method, implemented operationally in June 1972, begins by expanding the temperatures and the u and v components of the wind (separately) in a manner similar to the above. However, the smoothing technique is no longer applied; instead, a linear balance equation is inverted to obtain the heights of the pressure levels outside the octagon. This method removes most of the unwanted nonmeteorological features from this region. (Campana)

I. Primitive Equation Model Initialization

A method of initialization using a forecast model is being tested. The addition of a term to the u and v momentum equations allows a primitive equation model to be run under the assumption that the total derivative of horizontal divergence with respect to time is zero. This assumption eliminates gravity wave solutions from the PE model. The values of the extra terms are found by solving a Poisson equation each time step. The initialization scheme delays the filtering approximation one time step, so that gravity waves are removed from the $\tau-1$ fields but not from the τ fields. This delayed filter thus removes gravity waves generated by the mutual adjustment process between the mass and momentum fields. The procedure is iterated forward and backward in time until the wind and height fields have undergone sufficient mutual adjustment. This is considered the initialized state.

This method effectively damps gravity waves but not Rossby waves. The amount of damping depends on the wavelength of the gravity wave and the length of the time step. For certain combinations of wavelength and time step, the damping is total--and for nearly all combinations, the damping is significantly greater than that of the Euler-backward method.

Experiments with a one-layer, linear gravity wave model using cyclic boundary conditions revealed that this initialization method converged to the "correct" solution, provided that the initial winds were nondivergent. Tests were also made with a two-layer PE model in (x,y,σ,t) coordinates, again employing cyclic boundary conditions. These tests revealed that the initialization procedure converged to the same initialized state as the Nitta-Hovermale Initialization Method (Monthly Weather Review, Vol. 97, No. 9, September 1969), but in fewer iterations. However, in tests with a numerical version of the model investigated by Cahn (Journal of Meteorology, Vol. 2, No. 2, June 1945), which does not use cyclic boundary conditions, this was not the case. Although it again converged much more rapidly than the Nitta-Hovermale method, it attained an adjusted state similar to, but noticeably different from, the analytic solution obtained by Cahn.

Several tests have been made with a free-surface barotropic model on the 53 x 57 polar stereographic grid. Both the delayed filter and the Nitta-Hovermale methods showed some skill. However, it appears that it is not sufficient to reverse the direction of the time integration every time step, or even every few time steps. Rather, the integration must proceed in one direction for some time, probably at least 12 hours. The arrangement of a backward pass from t=0 to t=-12 hours, followed by a forward pass from t=-12 to t=0 hours, would allow the assimilation of offtime reports into the t=0 initialized data. (Dey)

J. Gravity Waves in Deterministic and Stochastic Systems

A number of calculations have been performed with a one-level spectral primitive equation model. Maximum simplification of the spectral components allows one to isolate purely gravitational modes and yet maintain nonlinearity. A changeable "reduced gravity" allows one to study various wave speeds, and the simplicity of the model allows one to investigate various gravity wave control measures quite economically.

The simplest possible nonlinear calculations of the semi-implicit method and of the "modified leap-frog" differencing system give results that are consistent with linear theory. The semi-implicit time integration scheme (which is far easier to incorporate in spectral models than in grid models) was found to produce highly accurate meteorological results with a 60-minute time step. Using a 10-minute time step with this scheme revealed that the gravity waves moved with slightly faster phase speeds than their analytically determined values.

The modified leap-frog integration scheme (Section G above) allows one to double the time step in PE models. The calculations revealed the slow-down of the gravity wave speeds and the linearly amplifying computational mode, again as expected from linear theory. The amplitude of the computational noise becomes significant and reveals the necessity of additional control measures in operational models.

When one views meteorological prediction as an initial value problem couched in random or stochastic terms, there is a new way for the wind and the mass fields to achieve balance; gravity wave energy becomes dispersed through "phase space" and the expected solution approaches the balanced state. Monte Carlo and stochastic dynamic calculations appropriate to the above simple spectral model gave an isolated look at this process. To summarize the limited calculations, one might conclude that this method would be sufficient for general circulation studies. However, for short-range predictions, the approach is not yet feasible economically because of the large amount of computer time involved. (Fleming)

K. Finite-Difference Formulation

The fourth-order accurate finite difference approximation of advection, based on the semimomentum scheme, was tested using the one-dimensional problem studied by Crowley (Monthly Weather Review, Vol. 96, No. 1, January 1968). A manuscript reporting the results has been submitted for review. Earlier efforts to test the scheme on real data, employing a barotropic model, proved to be inconclusive. In two cases, we found that 24-hour forecasts were sensibly the same with the fourth-order and second-order schemes. Basically, the errors associated with the use of the barotropic model were much greater than differences between numerical techniques. This fact negated the significance of employing real data. Further work on the method with realistic data is planned within the context of the project described in Section E above.

The conservation of potential vorticity theorem of Ertel (cf. Greenspan, Theory of Rotating Fluids, Cambridge University Press, London, 1968, 327 + xii) has been derived in σ coordinates. An office note is in preparation suggesting the possibility of using this conservative quantity to diagnose the significance of numerical truncation errors for the meteorologically significant component of the circulation predicted in forecast models. (Gerrity and Scolnik)

L. Implicit Integration Methods

The semi-implicit method has been formulated for the 6L PE model of Shuman and Hovermale. Progress on this project is described in Section E above.

Preliminary consideration has been given to the application of the method to equations expressed in polar coordinates.

The two-level semi-implicit model reported in NMC Office Note 65 has been integrated successfully using a fully staggered spatial grid lattice. A 48-hour forecast was obtained in 105 seconds on the CDC 6600, and the results were quite similar to those reported in NMC Office Note 65. Although the results are encouraging, the staggered grid does not appear to be as promising as the use of higher order differences on a conventional lattice. Therefore, this project has been shelved.

Further experiments with one- and two-dimensional PE barotropic models have been made on a limited area, in an effort to cast some light on the use of constant lateral boundary conditions with explicit and implicit integration methods. These experiments have demonstrated that when both heights and winds are held constant at the boundaries, the gravity wave responds differently in an explicit than in an implicit model. This difference makes the use of parallel runs of explicit and implicit models as a checkout procedure somewhat hazardous.

Also, a comparison of two different types of near-boundary lateral diffusion was made with an implicit PE barotropic model. One type corresponds to the procedure used in the LFM, the reduction of calculated tendencies at a rate proportional to the distance away from the boundary. The second procedure employs essentially the first step of the Lax-Wendroff method (cf. Gerrity and McPherson, 1969, NOAA Technical Memorandum NMC-46) at the first interior points. In the one-test case, the Lax-Wendroff method proved to be superior in controlling noise near the boundary which threatened the stability of the integration.

The experiments have been documented in a paper entitled "On the Use of Temporally-Invariant Lateral Boundary Conditions with Explicit and Semi-Implicit Limited-Area Integrations," presented at a seminar on numerical weather prediction in Stockholm, Sweden, May 22-26, 1972. (Gerrity, McPherson, Scolnik, Gordon)

M. Mountain Waves

During this period, work on mountain waves was largely completed. Both a hydrostatic nonlinear and nonhydrostatic linear numerical model have been used to investigate the causes of overturning, called rotor flow or jump-type flow in nature, to the lee of a mountain chain. It was found that the nonhydrostatic influences tend to dominate for smaller wind speeds, while nonlinear influences dominate for greater wind speeds. Further, nonlinear influences appear to cause overturning only in the lowest layers. A complete report of this work is being written. (Collins)

N. Upper Air Branch (UAB)

1. Analysis of Stratospheric Data

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

The stratospheric analysis program (70-, 50-, 30-, and 10-mb levels) is being run daily at 1200 GMT as part of the NMC final operational analysis on the CDC 6600 computer. Results are being monitored by UAB personnel. Display techniques of data and analyzed fields are being developed by Data Automation Division personnel. (Johnson)

b. Meteorological support of supersonic transport (SST) operations.

Regression equations have been developed for first guess of the analysis at 70 mb (cruising level of the Supersonic Transport).

(Johnson, McInturff, and Finger)

c. Comparison of SIRS retrievals with radiosonde data.

A comprehensive effort is continuing to determine the compatibility of SIRS-B retrievals with radiosonde data at stratospheric levels. (Finger, Johnson, Gelman, McInturff, and Miller)

d. Improved first guess for SIRS retrievals.

A statistical regression technique for obtaining a first-guess temperature profile at high stratospheric levels has been developed in cooperation with NESS for use in the SIRS retrieval process. Operational retrievals in the stratosphere since implementation of the technique in November 1971 appear to be considerably more compatible with radiosonde data than retrievals obtained previously. (Gelman and Miller)

e. Southern Hemisphere temperature analysis.

A Southern Hemisphere 14-level temperature analysis program has been developed to provide NESS with first-guess information for Vertical Temperature Profile Radiometer sounding retrievals when this instrument is launched, probably in September 1972. (Johnson)

f. Thickness specification.

The relationship between radiance (as measured by SIRS and the British Selective Chopper Radiometer) and the thickness of stratospheric layers with lower boundaries at 100 to 10 mb has been investigated. Layers exhibiting optimal thickness-radiance correlation (to 0.98) have been identified, and a technique has been developed for using measured radiances to specify hemispheric thickness fields which, by addition to the lower boundary height field, give synoptic maps at heights above the 10-mb level. (Quiroz and Gelman)

g. Rocketsonde data exchange and analysis.

Since January 1972, the United States and the Soviet Union have been exchanging meteorological rocket data for special inter-hemispheric stratospheric and mesosphere studies. On a reimbursable basis, NMC will perform research for the United States. Weekly synoptic analyses at the 5-, 2-, and 0.4-mb levels are being performed using all available rocketsonde, radiosonde, and satellite data.

(Finger and Gelman)

h. Empirical radiation corrections.

The calculation of mean monthly day-night temperature and height differences for stratospheric levels is continuing for newly introduced radiosonde instruments. The results are being used to adjust daytime radiosonde reports to make them compatible with nighttime values. (Finger, McInturff, and Johnson)

2. Research on Stratospheric Circulation.

a. Baroclinic instability forced from below.

A two-level model has been developed that allows us to examine the effect of vertical flux of eddy kinetic energy by the pressure-work term at the boundaries on the baroclinic instability of the layer. Preliminary results indicate a marked increase in baroclinic instability even with zero convergence of eddy kinetic energy.

(Miller and Johnson)

b. Stratospheric warming.

An extensive study of the stratospheric warming during the winter of 1969-70 has indicated that a major impetus for that event was 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. Researchers have found that during certain periods, the vertical energy flux in particular wave numbers is from 1000 mb upward rather than the opposite sense, as is observed in the mean.

(Miller, Brown, Campana, and Johnson)

c. Empirical study of critical-layer theory.

A pilot study of quasi-geostrophic potential vorticity transport, before and during stratospheric warming episodes, indicates that significant generation of potential vorticity occurs in the initial stages of stratospheric warmings. This generation of potential vorticity is related to a critical layer or layers. Further numerical studies are underway. (Johnson)

d. 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. (McInturff and Miller)

e. Hemispheric temperature analysis.

Radiances measured by SIRS have been used to depict stratospheric temperature changes in both Northern and Southern Hemispheres during autumn transition periods. (McInturff and Fritz)

3. Quality Control.

a. NWS Quality Control Working Group (QCWG).

The NWS QCWG continues to meet about once a month under the chairmanship of the NMC member. The group deals mostly with significant operational data problems that affect NWP activities. During the past 6 months, emphasis has been placed on improving the quality and availability of rawinsonde data from Alaska, notably those from Adak. Activity reports are provided routinely to specific staff offices at NWS Headquarters and NMC. (Thomas)

b. Marine data.

The Upper Air Branch was asked to prepare a reply for the NOAA Administrator in response to a WMO inquiry regarding the collection of upper air reports from mobile ships. UAB, having performed the only "controlled" studies on this subject in recent years, was able to provide an objective answer. The report showed that NWP usage of data from U.S. moving ship radiosonde programs had improved significantly since 1969, whereas the raob data from transient foreign vessels were generally of degraded quality and often were received either late or not at all. (Thomas)

c. Statistical summaries and their applications.

Statistical summaries of the relative volume of rawinsonde data being processed at discrete operational deadlines are being distributed routinely to interested NWS management offices. These statistics can be used to identify chronic problem areas in data acquisition. This enables staff offices to concentrate attention and resources on isolating and correcting the causes for data losses from NWP activities. The summaries for individual stations are being summarized further to reflect regional "performance," and these are being published monthly in the NMC Newsletter. (Thomas)

d. Rawinsonde data deficiencies.

A cooperative study to determine the causes for deficiencies in operational rawinsonde data was undertaken in cooperation with one NWS region. Preliminary findings show that, out of a sample of more than 38,000 data groups, 75 percent of all NWP data losses are a result of:

(1) On-station delays in transmitting data (39 percent).

(2) Errors occurring when reports are prepared for transmission (36 percent).

Contrary to much popular belief, data losses due to electro-mechanical communications problems were relatively low and accounted for less than 25 percent of the total. Of these, two out of three were apparent when they happened and could have been acted upon immediately at the data sources. (Thomas)

e. Study of day-night humidity differences.

Research has begun to learn whether radiation effects on upper air humidity measurements can be determined and accounted for. Daily comparisons of the day-night differences of mixing ratios vs solar elevation angles and other likely relationships are being made for each station in the world. This allows a determination to be made of the radiation effects on each type of instrument.
(Finger, Johnson, McInturff, Thomas)

f. Review of the UAB quality control program.

A synopsis of 4 years of quality control projects and their effects on NWP activities is being written for publication. The review describes procedures used to improve the quality of operational rawinsonde data and illustrates the measure of success attained with each major undertaking. (Finger and Thomas)

IV. EXTENDED FORECAST DIVISION

A. Evaluation and Adaptation of Extended-Range Numerical Predictions

1. Daily max-min temperatures for the period January 1, 1948, to December 31, 1965, recorded at the 143 United States and Canadian stations of the Klein-Lewis array (Journal of Applied Meteorology, Vol. 9, No. 3, June 1970) have been checked, corrected, completed, and written on a single archive tape. (Durdall and Gilman)

2. A program has been developed to create world and United States background maps on any projection with the FR80 microfilm device. It incorporates latitude-longitude positions from a tape of A. V. Hershey of the Naval Weapons Laboratory. First use has been the analysis of some 30-day mean charts of the Northern Hemisphere on a polar-stereographic projection. (Durdall and Gilman)

B. Vertically Integrated PE Model

Efforts to integrate in time the vertically integrated PE model continue. The vertical eddy terms are climatological, and the model is still adiabatic. The initialization procedure is still being considered. Experiments with NMC data suggest an inconsistency between the surface pressure gradient and the topography gradient, giving rise to unreasonable accelerations. Attempts to cope with this problem by designing a scheme with "consistent" truncation error have not been successful. At present, balanced winds are computed using an equivalent height field obtained from a Poisson equation. The boundary conditions of the Poisson equation caused a diversion into time-varying boundary conditions that result in systems of algebraic equations. The purpose was to obtain compact and efficient matrix methods for such generalized boundary condition problems. (Sela)

C. Computer Applications Section Activities

1. The major effort during this period has been the conversion of programs, operational and utility, from the IBM 7094 and 1401 to the CDC 6600--now about 95 percent complete.

2. Continued refinement and expansion of a disk data storage system have been made to provide random access to all data required for extended range forecasts, all local verification, statistical studies, archives, etc., within a 36-day period. Maintaining such a system in the CDC permanent file environment with any degree of reliability has presented a multitude of problems; however, the historical observed and forecast data files are expected to be operational by July

1972. An office note is being prepared to describe the contents of these files and any special requirements for their use.

3. A summary of the past 25 years of sea level pressure, 700-mb heights and 700-mb temperatures has been made in response to a request from the Portuguese Government. Products available at this time are complete monthly mean tape files, 1947-51, and summaries of the monthly means for each month (climatological means). These data are now in polar coordinates, but when time permits they will be converted to an I,J grid for graphical output and possible publication. (Gelhard)

V. DATA AUTOMATION DIVISION (DAD)

A. Statistical Techniques and Analysis Branch

1. Objective Analysis

a. Operational implementation of analysis programs discussed in the preceding NWP Activities, NMC, Second Half 1971 report (see Chapter V, Section A.1.a.) took place during the reporting period; consequently, the IBM 7094 computer is no longer used in the production of the analyses but is used only for output processing. The operational procedures followed are to (a) dump the observational data from the IBM 360 system and transfer them to the CDC 6600 system, (b) perform the analyses on the 6600, and (c) transfer the fields to the 7094 for output processing. The above switchover occurred on the following dates:

RADAT (1+30)	1200 GMT	May 3, 1972	
OPNL (3+25)	0000 GMT	June 21, 1972	
FINAL (10+00)	1200 GMT	June 23, 1972	(DAD Staff)

b. The changeover from manually produced to CDC 6600 machine-produced 500-mb analyses for national facsimile (NAFAX) charts N10 and N77 occurred 1200 GMT May 15, 1972. (See B.2.b.) On the same date, the 700-mb analyses for NAFAX charts N20 and N86 were switched from the IBM 7094 to the CDC 6600 computers. A similar changeover from manual to machine 850-mb analyses for NAFAX charts N12 and N79 occurred 1200 GMT May 30, 1972. These analyses are all done on the LFM grid. (DAD Staff)

c. The preanalysis processors on the 6600 system were modified to accept the surface and upper air reports in several files. It is now possible to load the different files independently, if desired, and have this single code prepare the single files to be used by the analysis programs. The upper air preanalysis processor was modified to extrapolate aircraft from flight level to constant pressure levels in the tropical regions, using the 12-hour forecast wind shear from the two-level (700- and 300-mb) tropical forecast program. The same code was also changed to interrogate the surface file to secure the station pressure, temperature, and dewpoint when this information is missing from a radiosonde report. This information is helpful in salvaging values to use in the moisture analysis program. (Costello)

d. Fine-mesh moisture analysis

When radiosonde data are not available for the fine-mesh moisture analysis program, inferences are made from surface synoptic reports to estimate the relative humidity (RH) for the boundary and the two lower tropospheric σ-layers for the LFM model. These estimates were determined by correlating cloud height and amounts, present weather type, and surface RH with calculated RH values from radiosonde reports for about twenty synoptic cases. Since August 1971, a large data base has been saved for additional, more comprehensive correlation studies. A recent preliminary study of these data indicates that there are definite geographical, seasonal, and diurnal variations of the mean σ-layer RH values associated with clear skies. Based on a 9-month collection, the procedures for inferring RH estimates when no low and middle clouds are reported have been modified. The changes became effective at 1200 GMT June 5, 1972. Details of the changes are described in Technical Procedures Bulletin No. 75. (Desmarais)

e. Motion-moisture test

Tests were made to evaluate the differences between the operational analyses obtained with the IBM 7094 package and the analyses done on the CDC 6600. The procedures used in each package are not identical, and some differences are to be expected in both the motion and moisture analyses. Accordingly, separate 6L PE forecast runs were made with the possible combinations of moisture and motion fields. Results indicated that the forecasts were quite similar over most areas and that in a few cases the differences were only minor.

(Desmarais and Stackpole)

f. Detection and correction of errors in height and temperature analyses

Examination of temperature and thickness temperature soundings from NMC isobaric analyses occasionally has shown discrepancies in lapse rates much larger than should be expected by the analysis procedures. Initialization for the 6L PE model requires that analyzed heights be interpolated into their σ coordinate system, discarding the mean temperatures obtained by the temperature analyses but using the analyzed temperature lapse rates. Since the height and temperature analyses are not done simultaneously, occasional bad heights or temperatures creep into the analyses. Vertical consistency checks will usually indicate levels or layers where the mean temperature, obtained by thickness considerations, disagrees with the mean temperature obtained from isobaric analyses. Actually, these two mean temperatures do not have to agree exactly, but the differences should not be very large.

Shuman (NMC Office Notes 67 and 68) has described a method for bringing erroneous multilevel analyses into reasonable agreement. The method uses the hydrostatic equation to determine measures of disagreement, ε_k, between two estimates of temperature lapse and two estimates of mean temperature,

$$\varepsilon_k = \frac{Z_{k+1} - Z_{k-1}}{\Delta_k} - \frac{T_{k+1} + T_{k-1}}{2g/R}$$

where

$$\Delta_k = \ln(1000/p_{k+1}) - \ln(1000/p_k).$$

The weighted sums of squared (I) of ε_k

$$I = \sum_{m=1}^{8} \Delta_{2m+1} \, \varepsilon^2_{2m+1}$$

is differentiated by one of the heights and by one of the temperatures, 700- to 150-mb inclusive, and then minimized.

Several fine-mesh test cases have been evaluated with this method, and the results indicate that the procedure can detect and correct height and temperature analysis errors. Vertical consistency checks of the adjusted fields show that most of the original gridpoint disagreements can be resolved. PE initialization from these adjusted fields has been used as input to the LFM model, and the forecasts showed a slight improvement. The method does seem to have merit, and plans are being made to incorporate the scheme as a pre-initialization analysis adjustment to the LFM package. Similar adjustments will be included for the operational 6L PE initialization at a later time.

(Desmarais and Shuman)

g. Tropical analysis

The tropical analysis program was modified to include analyses of wind and temperature for the 850-mb level, and also to prepare the output for displaying the analyses by Varian or facsimile. A feature has been added which allows the location of tropical storms to be indicated both on the display chart and in the chart label. For the display, the wind flow representation has been switched from streamfunction lines to stream lines using a program developed by Elbert Hill of the National Hurricane Center (NHC).

Some testing has been done to introduce the climatological position of the intertropical convergence zone (ITCZ) into 850-mb analyses. (Irwin)

2. Updating Asynoptic Reports

A report summarizing the tests conducted to evaluate methods for updating asynoptic reports to a synoptic time for possible use in operational analyses has been completed and will be available as an NMC office note. Overall results show that the Tendency Method, described in <u>NWP Activities</u>, <u>NMC</u>, <u>First Half 1971</u> (see Chapter IV, Section A.2.), is better than advective methods or persistence for updating height and temperature reports that are 12 hours old.

(Desmarais)

3. Machine-Processed Observations

a. The IBM 360 surface and aircraft decoding programs have been rewritten to use fully the expanded storage facilities of the 660 disk. This will permit storage of surface reports from all land stations currently being transmitted and from a total of 3,000 ships. The land station and ship dictionaries can be initialized from a master tape file.

Programming was completed on a task to provide information for surveys of bulletins received on the teletype facilities.

A program was implemented that provides tapes containing the hourly (Airways) data transmitted on Service A. The principal user of these data is the Techniques Development Laboratory.

A program was implemented that extracts, decodes, reformats, and stores aircraft reports received from the Aeronautics Incorporated (AIRINC) facilities in Cedar Rapids, Iowa. These additional reports will be added to the aircraft file as soon as possible. The aircraft decoder was expanded to extract and save the constant pressure level and dropsonde data from reconnaissance aircraft. (Byle)

b. The program that dumps the surface data for input to the CDC 6600 system was modified to separate the reports into three files: (1) a file containing land stations; (2) a file containing all ships; and (3) a file containing the manually derived reports (monitoring bogus and estimates of moisture from satellite cloud pictures).

A program was written that summarizes the receipt by time of surface reports from land stations. Work is underway to expand the capabilities of this program to handle surface reports from ships.

Several operational codes are in the process of being modified to use the increased capabilities of the 660 disks.

A new program was initiated that will result in the automation of the computation, coding, and transmission of the monthly CLIMAT message by making use of the data collection and storage capabilities of the IBM 360 system. Except for those stations not reporting four times daily on Service C, all the land stations will be processed. Incorporating the ocean station vessel (OSV) reports will be done at a later time. (Fleming)

c. An operational program was written to handle the loading of all manually prepared card input (bogus) for the 360 system. The code, which dumps upper air data for the 6600 system, was modified to output the upper air card input (monitoring bogus and wind estimates from Applications Technology Satellite (ATS) and from cirrus plumes), and also to output the constant-pressure level data from reconnaissance aircraft.

A program was initiated which will result in capability to summarize by receipt time the different parts of the upper air messages (for example, parts AA, BB, CC, and DD of the radiosonde information).

Several operational codes are being modified to use the 660 disk files. The expanded area will allow storage of data for a period of 24 hours. (Webber)

d. Programs were written and implemented on the 6600 system that will list the data found in the upper air files and supply an abbreviated list showing the receipt or nonreceipt of the mandatory level parameters (height, temperature, and wind), the surface parameters (pressure, temperature, and wind), and of the tropopause parameters (pressure and temperature) for each station in the file containing the radiosonde and upper wind reports.

A program was written for the 360 system that will list the data found in the upper air files that are prepared for input to the 6600 system. This provides additional capability to list the data being loaded into the 6600 system.

Work is continuing on the program to detect errors in radiosonde data by use of the relationship between height and temperature expressed in the hydrostatic equation. (Costello)

4. NMC-NHC Activities

The adaptation of the NHC operational codes which forecast hurricane motion (NHC-67, -72) was undertaken to permit running these codes on the CDC 6600. This has been completed and successfully used as guidance for Agnes, the first hurricane of the season.

The development of a computer-generated analysis to replace the hand-drawn ATOLL (analysis of tropical oceanic lower layer) chart for the NHC has been accomplished. It includes a relocatable grid with first guesses provided by the global spectral analysis, data checking features, an ITCZ bogusing section that reduces the probability of errors in bogus cards by modeling this large-scale feature, and output compatible for the Varian when installed in Miami. Enlargement of the area over which the analysis is performed is underway and should be implemented shortly, thus permitting the discontinuance of the hand-drawn chart. Observations, streamlines, and isotachs on a Mercator map are now being sent to NHC on the facsimile network once per day.

An investigation into time-dependent boundary conditions is underway. The work completed has established the physically sound assumption of specifying fine-mesh forecast boundaries with coarse-mesh forecasts. A filtered barotropic model has been run out to 72 hours with such boundaries. It appears to be at least as good a forecast as with fixed boundaries and appears stable for a longer integration. Experiments are also underway with a primitive equation barotropic fine-mesh model; the model has been run to 48 hours stably; however, two-grid-increment waves appear in the vorticity and divergence fields. A solution invoking boundary viscosity or smoothing is sought. It is intended to use this technique, if it proves satisfactory, for the filtered barotropic hurricane model called SANBAR now used at NHC.

Archiving of the Eddy analyses used as input for the SANBAR model has been completed. This will permit easy rerunning of interesting cases for a period of a month following the actual storm occurrence. (Zbar)

5. Miscellaneous Programs

a. Climatological data

The Data Automation Division has received copies of Northern and Southern Hemisphere climatological grid data tapes produced by joint efforts of NCAR, NOAA, and National Weather Records Center. These data tapes, written in Binary Coded Decimal (BCD) format, contain monthly means of sea-level pressure, temperature, and dewpoints; isobaric heights, temperatures, and dewpoints, geostrophic wind components, total geostrophic wind; and standard deviations of monthly mean temperatures, dewpoints, and heights for a 5° latitude-longitude grid. The BCD tapes have been reformatted to provide these same climatological data fields in binary format. Separate tapes are available for (a) 5° latitude-longitude grid; (b) NMC coarse mesh (53x57) grid, and (c) NMC fine-mesh (53x57) grid. Dewpoint values are available only for the surface, 850-, 700-, and 500-mb levels. Monthly RH values are being studied for possible use in the moisture analysis programs. (Desmarais)

b. Utility gridprint program

A utility program, NWPK04A, is available for use on the CDC 6600 computer to gridprint any NMC data field properly identified in NMC Office Note 28. The program will allow the user to search a maximum of 30 NMC files for up to 100 desired data fields to be gridprinted at 8 lines/inch with contouring. Desired fields are specified by data cards input to the program. In addition, user options are available for modifying the programmed print constants for any field. Details for using this program are available through the Librarian, Data Automation Division. (Desmarais)

c. Relative humidity verification

A program has been written to verify (a) the 12-hour PE relative humidity (RH) forecasts used in the moisture analysis program, (b) the 12- and 24-hour LFM RH forecasts, and (c) the inferred RH estimates obtained from surface reports. Verifications are made against computed mean σ-layer RH values obtained from radiosonde reports. (Desmarais)

d. Programming support

The following subroutines were written and made available for use in the CDC 6600 NMC library:

W3FE03 - Short-dump SCOPE standard binary files

W3FE04 - Short-dump SCOPE nonstandard binary files

W3FE05 - Dump coded ADP reports

W3FE06 - Locate an NMC file on a multifiled magnetic tape

W3FE08 - Load an NMC file as a local file for use as random access disk file

W3FE09 - Locate an NMC file on a multifiled SCOPE nonstandard magnetic tape

W3FE10 - Load an NMC file as a local file for use as random access disk file from a SCOPE nonstandard tape.

(Desmarais)

B. Programming Branch

1. Program Conversion

The conversion of NMC operational programs from 7094 assembly language to 6600 FORTRAN has been completed. (Staff)

2. CDC 6600 Computer Operations

a. With the exception of some map generating programs, all NMC's operational programs are being run on the CDC 6600. (Staff)

b. The PLOTFAX program was developed and implemented during this reporting period. This program generates charts with observations plotted and isolines of geopotential and of temperature drawn on a 1:20 million Polar Stereographic map background.

This PLOTFAX program was put into operation and began generating 500-mb and 700-mb charts for facsimile transmission on May 15, 1972. The 850-mb chart was added on May 30, 1972.

(Shimomura, Schnurr, Dent, and Hopkins)

c. A version of the 6L PE forecast model, with a 15-minute time step (instead of 10-minute) went into operation April 12, 1972. Though a saving of 10 minutes central memory time was made, there was no change in elapsed time for the 48-hour forecast.

On May 19, 1972, the 20-minute time step version of the 6L PE model went into operation. This change saves another 10 minutes of central processor time and about 15 minutes of clock time. However, 9 minutes of this saving in clock time is used by additional operational jobs run in parallel with the PE forecast. (See Chapter III, Section G, above.) (Bedient, Carlton, Stackpole, Brown, Campana)

d. A change in the LFM model from 5-minute time steps to 6-minute time steps was made beginning with the 1200 GMT run May 31, 1972. A saving of about 6 minutes has been made. This time is now used to run the operational analysis program. (Howcroft)

e. The 6L PE, which had been running at final time (10 hours after observation time) since May 9, 1972, has been used as the first guess for the next operational cycle since June 20, 1972. The FINAL continues to be run only from 1200 GMT data. (Staff)

3. Computer Graphics System

a. Work continued on the PEPFAX output code, which will provide FAX/VARIAN maps to replace the maps drawn by the 7094. The program will go operational on the 6600 as soon as the 360 systems are upgraded to handle the increased workload. (Schnurr and Hopkins)

b. A special 6600 FAX/VARIAN Schedule program has been written. The program should provide a better means of managing and identifying output display map sets. (Schnurr)

c. Work continues on a thinning subroutine for reducing overplotting of observations on plotted charts. (Dent and Shimomura)

4. FOUS Transmission

Two stations, Del Rio, Tex., and Rapid City, S. Dak., were added to the FOUS transmission effective April 4, 1972. At the same time, slants were substituted for 9's to indicate missing data. (Gordon)

5. Benchmark Programs

A small set of representative NMC operational programs have been put together to be used as benchmarks. These programs, together with those from other NOAA agencies, will be used by the Computer Division as aids in the selection of replacement equipment for the CDC 6600 computer. (Allard, Steinborn, and Kneer)

6. Bureau of Reclamation

The data area for the transmission to the Bureau of Reclamation was enlarged and additional fields included beginning May 2, 1972. (Kneer, Allard, and Tyler)

C. <u>Information Processing Branch (IPB)</u>

1. On January 1, 1972, various codes (including the upper air decoder and the international transmission code) were revised to inaugurate the new upper air changes to TTAA, TTBB, etc.

2. On January 3, transmissions started on a new circuit (7073) to the National Hurricane Center at Miami.

3. On February 7, with the help of IBM customer engineers, a vexing problem was solved on our dial-up phone which had been causing our high-speed Honolulu and Carswell circuits to drop out.

4. On February 18, binary data (parts of 6600-generated data fields) were transmitted for the first time. This information was sent to Carswell AFB to be routed to Offutt AFB.

5. On February 24, final phaseout of the Adis line began as Kansas City took over the job of sending hourly bulletins through IPB to Toronto. The Adis line was laid to rest on March 29, when Kansas City shouldered the final remaining Adis responsibilities for relaying data to Toronto.

6. On March 1, the 2400-baud, bisynchronous full-duplex line to Bracknell was brought up on a limited operational basis. Initially, activity was confined to sending synoptic and upper air bulletins to Bracknell. Full operational implementation of this line and the corresponding demise of the Offenbach line are scheduled for later this year.

7. On March 6, operations began on the latest addition to IPB's electronic switch line - the Videojet printer. At the appropriate times (about 3½ hours after observation time, the dial phone is used to call the Environmental Protection Agency at Raleigh, N.C., and send them several CDC 6600-generated air pollution potential forecast products in the form of maps, teletype messages, and upper air soundings, printed as sent at 1050 words per minute (wpm).

8. On March 8, five Radar Reports and Warning Coordination (RAWARC) lines were added to the communication system, including two

100-wpm and three 75-wpm lines. A month later, a program was inserted to take radar (SD) bulletins received on one or more RAWARC lines and reformat them into new SD bulletins for distribution on other RAWARC lines.

9. On March 21, the name of the hurricane bulletin NHC67 was changed to WHXX1.

10. On April 4, after much work, operations began with a completely reassembled communication monitor. Among the features of this monitor was an expansion from two to three nonswinging disks, the third disk used for printer queues, survey data, and system dumps. Unless a survey is in progress, two disks can be used when necessary without creating a problem. Capabilities were also added to handle future requirements for a second batch area, a two-queue priority transmit scheme and low-speed polling.

11. On April 6, a 3-day survey was taken for WMO to record the time that selected bulletins entered our system and the time they were switched out to Tokyo, Offenbach, Brasilia, and Buenos Aires. Several programs were specifically developed or revised to handle this survey request and all similar, future survey requests on short notice.

12. On April 19, a new procedure was established in our communication computer to dump all of core onto the third disk on every restart with a complementary DOS code to specially print it. This capability has helped to zero in on the solution to some problems afflicting our communication system. One such problem that was solved concerned the swinging disks, and turned out to be unexpected interrupts that were not being handled properly by our communication system.

13. On May 2, transmission of 19 FUXX (grid point) bulletins to the Bureau of Land Reclamation in Denver began.

14. On May 12, the gradual de-emphasis of transmission tapes in favor of disk commenced. For the first time, transmission bulletins were generated via the DOS system onto a swinging disk for processing and distribution on our communication system. Currently, an SD and an ABUS bulletin are generated and transmitted in this manner.

15. On May 15, SOVD1-5 (Bathyscope) and FUAI1-5 (grid-point) bulletins were added to our transmission repertoire.

16. On May 17, the 7094-generated SMNA bulletin to Russia was dropped and replaced with 360-generated 6-hourly (SM) bulletins (SMUS, SMCN, etc.).

17. On May 24, the FSNT5 bulletin (72-hour surface pressure) was added for transmission to the Scandinavian countries.

18. Various changes were made to the upper air processors:

a. A correction element to process upper air reports that have been corrected by the cathode ray tube (CRT).

b. The logging of fixed and moving ships for CRT display.

c. Insertion or deletion of bogus latitude-longitude entries, submitted by the CRT, into the upper air dictionary.

d. Retention of all processed bulletin headings.

19. Various changes were made in the CRT codes to:

a. Allow Tech Control to process unknown queues in two CRTs simultaneously.

b. Display up to 2500 upper air bulletin headings (and allow the retrieval of complete bulletins).

c. Display 212 character disk records.

20. On the average, new bulletin directories were prepared every 2 weeks for the communication system.

D. Operations Branch

1. The operational balance equation was modified to produce a vorticity field from the stream functions, and include the field within the radat analysis file on the CDC 6600.

2. The operational jobs on the CDC 6600 were completely documented.

3. Routine maintenance was provided on IBM 7094 and IBM 360 programs.

4. Routine archiving and data type stacking were performed.

5. Systems modifications on the IBM 360s included:

a. Disk Operating System (DOS) Power II Ver-4 (SPOOL) was added to Release No. 24. This new SPOOL package contains many new IBM changes and internal modifications to simplify operations. One notable change is being able to start a printer writing task from the beginning or from a specific page. This eliminates the duplication of print when there is a need for restarts.

b. Modifications have been made to DOS attention routines (AR), so as to simplify operator intervention for starting F1 and F2 (partitions) programs. The typing of the job name, for execution, has been eliminated. All that is required is the typing of START F1 or F2, and the program is automatically started. Other operator entries have also been simplified for ease of operation.

c. A new background (BG) routine has been added to 360 system No. 3 operations which makes a regular check to see that SCRTS (F2) program is active and running. If program is not active, a message is printed on the keyboard to remind the operator to start the partition.

d. A program is being written to compute the daily means for selected weather service stations. The daily means will be computed and stored on disk. At the end of the month, a tape will be written for the running of existing system 360 programs. This program will be added to system No. 3 operations (once a day) and will replace the present IBM 7094/II program.

E. <u>Electronic Equipment Branch (EEB)</u>

1. Digital Facsimile

a. Tests were run successfully between Suitland and the Gramax Building using the DACOM units. (See Chapter V, Section E.3., <u>NWP Activities</u>, <u>NMC</u>, <u>Second Half 1971</u>.) One of the output lines of the Digital Facsimile Interface (DFI) No. 2 was modified and some electronic circuits added to make the DFI appear as a digital scanner to the DACOM unit. A clock of 14,400 cycles (480 rpm) was furnished to the DACOM along with facsimile data from the 360 system. This in turn was compressed (reaching close to a 2:1 packing ratio) and sent through a 4800-baud modem over telephone lines to a receiver modem and receiver DACOM unit in Silver Spring. The data were decompressed and generated on a digital recorder at 480 lines per minute. After modifying the DFIs to conform to IBM standards, it was determined that the IBM 360/30 could not drive eight facsimile circuits simultaneously as planned. Tests were then made on the IBM 360/40. The DFIs had to be remodified to accommodate the faster Multiplex Channel. The tests were successful in driving all eight facsimile circuits and running background jobs and other channel devices at the same time. A third DFI will be installed to back-up the other two when they go into full operation.

2. Output Fax via DFIs Using PACFAX Units at 240 rpm

To accommodate this faster speed, the data have to be frequency-compressed to be transmitted out on the telephone line. PACFAX units do the compressing and are installed in the facsimile room. The Branch designed, built, and installed circuits both in the DFIs and in the facsimile room to sense automatically when the faster speed was required. At that time, the PACFAX units are automatically switched in, then switched out when the chart is completed.

3. Data Transfer Between Suitland and NHC, Miami

The data link between Suitland and Miami consists of an Interdata mini-computer at Suitland and a Varian mini-computer with a magnetic tape unit and Varian Status 5 recorder at Miami. With the Miami system now at Suitland (soon to be shipped to Miami), it was the responsibility of the Branch personnel to provide the skill required to interface the two systems. The system will communicate via a 201 interface. After a few strapping problems were solved in the 201s and some minor modifications to the cards were accomplished, communication was established. Edward Hopkins has the task of writing the programs to successfully transfer data between the systems. When the Varian system is installed at NHC, Miami, transfer of data will be done via 203C Bell System modems over a 4800-baud full-duplex line.

F. Equipment Status

1. Memory Extension of 360/30

The IBM 360/30 Central Processor Unit (CPU) had its core memory doubled by adding an extended memory unit with 64K bytes of memory. Extending the memory beyond its design capacity required extensive modifications to the CPU's micro code. Subsequently, it took several weeks of engineering changes before all programs would run. In April, the 360/30's attempt to operate in a multiprogramming mode, i.e., computer facsimile and Sanders CRT began to result in machine checks. This was circumvented by running fax on the 360/30 and CRT on the backup 360/40. The decision to upgrade the 360/30 to a 360/40 was based on the need for more CPU power to run five more lines of fax.

2. Varian Graphics Plotter

The Varian graphics device generates over 80 maps every 24 hours. During FY73, the output of the Varian is expected to increase to 175-200 per day. The Miami NHC and Kansas City NSSFC terminals will record NMC digital graphics on magnetic tape over high-quality phone lines as part of the new Minifax network.

3. Uninterruptible Power (UPS) and Auxiliary Power (AUX)

The UPS backed up by AUX power provides NMC with a high degree of protection against power drops.

VI. FORECAST VERIFICATIONS--MONTHLY MEANS FOR 1972

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																		
Jan.	.77	180	16.1	268	23.7	.76	232	18.3	327	27.0				.72	289	23.6	360	28.4
Mar.	.78	172	15.8	259	23.0	.76	231	19.0	332	27.9				.78	246	20.7	367	29.3
May	.78	137	13.6	212	20.1	.80	164	14.8	273	24.0				.80	188	17.2	307	26.4
300 mb																		
Jan.	.83	165	15.5	293	27.0	.81	215	18.0	356	30.8				.78	255	21.3	388	32.3
Mar.	.85	151	14.6	280	26.1	.83	199	17.0	353	30.8				.83	222	19.8	392	33.0
May	.84	126	12.6	230	22.7	.85	155	14.8	294	27.1				.84	181	17.1	333	29.7
500 mb																		
Jan.	.82	127	11.4	214	19.8	.80	164	13.3	262	22.6	.70	190	15.5	.78	189	15.4	286	23.8
Mar.	.83	116	10.5	202	18.6	.82	152	12.2	255	22.0	.69	185	15.0	.82	168	14.2	286	23.7
May	.82	91	8.7	161	15.6	.84	113	10.4	208	18.8	.70	148	12.8	.83	132	12.1	236	20.7
850 mb																		
Jan.	.75	114	10.1	152	13.5	.74	140	11.3	184	15.2				.74	151	12.6	198	15.5
Mar.	.76	102	9.3	139	12.4	.76	128	10.6	176	14.5				.77	137	11.6	195	15.2
May	.74	78	7.7	106	10.0	.77	93	9.0	136	11.8				.77	102	9.7	152	12.7
1000 mb																		
Jan.	.80	117	11.5	182	17.4	.79	144	13.0	214	19.1				.74	160	14.9	230	19.6
Mar.	.79	105	10.8	160	15.6	.80	130	12.2	199	17.8				.77	144	13.7	218	18.6
May	.76	81	8.5	117	12.2	.73	96	9.9	146	13.8				.76	115	11.3	167	14.9

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																		
Jan.	.89	139	13.4	312	26.0	.84	207	17.9	377	30.1				.77	263	21.6	413	31.7
Mar.	.91	119	12.5	301	26.4	.89	176	17.5	396	33.1				.87	201	18.7	430	34.2
May	.85	118	13.0	208	20.5	.86	138	13.4	276	25.8				.86	158	15.8	321	29.3
300 mb																		
Jan.	.88	150	14.8	375	33.3	.87	216	19.6	442	37.3				.79	280	24.0	475	38.8
Mar.	.93	124	13.6	364	33.8	.92	171	17.4	459	40.2				.90	213	20.7	504	42.4
May	.88	105	11.5	229	23.1	.89	135	13.7	297	28.5				.89	158	16.2	349	32.3
500 mb																		
Jan.	.90	111	11.0	260	23.1	.85	156	13.9	307	25.6	.73	212	17.6	.79	195	16.4	334	26.9
Mar.	.92	93	9.6	244	22.7	.90	126	11.9	308	27.0	.83	167	14.8	.88	159	14.2	339	28.5
May	.88	70	7.6	152	15.0	.89	90	9.1	200	18.6	.79	123	11.6	.88	107	10.7	235	21.2
850 mb																		
Jan.	.86	92	8.9	171	15.2	.81	113	10.5	196	16.4				.78	135	12.2	208	16.5
Mar.	.87	76	7.7	148	13.6	.86	97	9.5	177	15.5				.82	116	11.1	185	15.4
May	.83	58	6.1	99	9.8	.84	72	7.2	130	11.9				.82	86	8.7	144	12.8
1000 mb																		
Jan.	.88	110	11.6	218	19.9	.86	131	13.3	251	21.4				.82	158	15.8	268	22.0
Mar.	.88	87	9.6	181	17.1	.87	111	11.4	214	19.1				.84	133	13.6	221	19.2
May	.78	71	8.0	115	12.2	.83	85	9.0	143	14.0				.78	115	11.7	166	15.6

C. <u>Europe--Area 3 (143 Grid Points)</u>

	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																		
Jan.	.80	157	14.5	293	26.9	.83	194	17.3	360	31.3				.78	239	20.3	383	32.1
Mar.	.84	162	15.5	302	26.1	.83	206	18.4	382	31.2				.82	252	21.8	453	35.4
May	.79	130	12.7	220	20.5	.80	164	15.1	278	24.5				.79	202	18.1	319	26.9
300 mb																		
Jan.	.88	162	16.0	351	33.5	.86	211	20.0	432	39.0				.82	257	23.0	465	40.4
Mar.	.89	162	16.3	353	32.3	.87	214	19.9	453	39.2				.85	259	23.6	517	42.8
May	.84	141	14.3	275	27.2	.83	183	17.8	344	32.3				.81	226	21.0	391	35.4
500 mb																		
Jan.	.86	126	11.8	264	24.7	.85	166	15.3	328	29.0	.76	210	18.0	.81	200	17.9	357	30.4
Mar.	.88	126	11.9	266	23.4	.86	164	14.7	341	28.6	.68	240	19.3	.85	201	17.3	397	31.9
May	.86	98	9.7	198	19.1	.84	132	12.4	252	23.1	.71	182	15.8	.82	164	14.9	289	25.7
850 mb																		
Jan.	.77	119	9.3	184	15.9	.74	151	11.8	222	18.4				.71	176	13.5	240	19.0
Mar.	.83	103	8.5	186	15.2	.81	135	10.6	242	18.6				.79	164	12.5	279	20.6
May	.79	77	6.9	127	11.6	.79	101	8.6	164	14.2				.77	122	10.2	188	15.7
1000 mb																		
Jan.	.80	120	10.1	200	17.7	.76	154	12.6	238	20.0				.71	184	14.9	252	20.6
Mar.	.85	105	9.2	196	16.6	.82	140	11.4	252	19.7				.79	176	14.1	290	21.9
May	.75	81	7.4	128	12.1	.79	101	9.0	163	14.4				.76	126	11.0	186	15.8

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																		
Jan.	.78	160	15.7	250	22.3	.75	226	18.6	310	26.1				.69	320	25.1	341	27.5
Mar.	.79	154	14.9	257	23.2	.75	216	18.1	322	27.1				.76	255	20.4	362	29.3
May	.87	119	12.6	247	23.4	.86	158	15.2	319	28.5				.82	191	17.5	357	31.0
300 mb																		
Jan.	.84	151	15.0	281	26.4	.79	222	18.0	345	30.7				.76	272	21.1	375	32.2
Mar.	.85	138	14.4	280	26.7	.82	194	16.9	343	30.4				.79	242	19.9	383	32.6
May	.90	120	13.1	275	26.9	.89	153	15.6	351	32.5				.87	183	18.0	390	34.8
500 mb																		
Jan.	.83	115	11.0	208	20.2	.81	150	12.5	249	22.8	.70	184	14.7	.75	192	14.9	270	23.9
Mar.	.83	104	10.2	190	18.4	.81	136	11.6	231	20.6	.65	173	14.1	.79	167	13.3	255	21.9
May	.89	85	8.9	185	18.2	.88	109	10.9	235	21.6	.75	153	13.1	.87	129	12.7	263	23.5
850 mb																		
Jan.	.71	121	12.3	141	12.4	.73	141	13.1	171	14.3				.66	171	14.1	182	14.6
Mar.	.75	106	11.5	137	12.4	.78	130	13.0	169	13.9				.75	151	13.6	185	14.5
May	.77	92	11.1	126	11.9	.78	113	13.0	155	13.7				.78	117	12.9	168	14.6
1000 mb																		
Jan.	.80	115	11.5	180	16.8	.82	132	13.1	214	19.0				.76	167	15.1	229	19.6
Mar.	.81	104	11.0	171	16.3	.84	116	12.5	207	18.0				.81	148	14.4	227	18.8
May	.84	84	9.3	147	14.6	.81	112	11.6	180	16.6				.81	120	12.6	191	17.4

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.

VII. MACHINE PERFORMANCE AND USE

A. <u>IBM 7094/II</u>

1. Profile - No changes.

2. Use - 2,319 hours.

B. <u>IBM 360/30</u>

1. Profile

a. Leased equipment:

1 Data Recall 64K Extended Memory Unit	1-72.

2. Use - 3,703 hours.

C. <u>IBM 360/40</u>

1. #1 Profile

a. Purchased equipment:

1 Memorex 661-1 Disk Storage Controller	6-72
1 Memorex 660-1 Disk Storage Unit	6-72.

2. Use - 4,292 hours.

D. <u>IBM 360/40</u>

1. #2 Profile - No changes.

2. Use - 3,414 hours.

E. CDC 6600, Computer Division, NOAA

1. Profiles (3 systems)

a. Leased equipment:

1 - 6612 Central Processing Unit (CPU)
1 - 6613 Console
1 - 3423 Magnetic Tape Converter
2 - 10010 Long-Line Driver Modifications
2 - 6846 Modified to 6671
1 - GK122 Channel Switch
1 - GK130 Channel Switch
1 - 3624 Tape Controller

b. Released equipment:

1 - 6601 Central Processing Unit (CPU)
1 - 3228 Magnetic Tape Converter

2. Utilization for NMC work:

Central Processing Unit - 2,036 hours
Peripheral Processing Unit - 2,507 hours

VIII. PERSONNEL CHANGES

A. Development Division

1. Alonzo Smith, Jr., Technical Assistant, transferred to the Office of the Associate Administrator for Environmental Monitoring and Prediction, NOAA, February 20, 1971.

2. Joseph A. Ships, Jr., Office of the Director, NMC, joined the staff of Development Division as Technical Assistant, April 16, 1972.

B. Analysis and Forecast Division

1. Robert O. Cole, Deputy Branch Chief, Basic Weather Forecast Branch, transferred to Jackson, Miss., January 22, 1972.

2. George W. Rippen, Automated Analysis Branch, transferred to Weather Service Forecast Office, Atlanta, Ga., January 22, 1972.

3. Robert Kuessner, Aviation Weather Forecast Branch, transferred to San Juan, P. R., March 18, 1972.

4. Jack D. Cox, Quantitative Precipitation Forecast Branch, transferred to Memphis, Tenn., June 10, 1972.

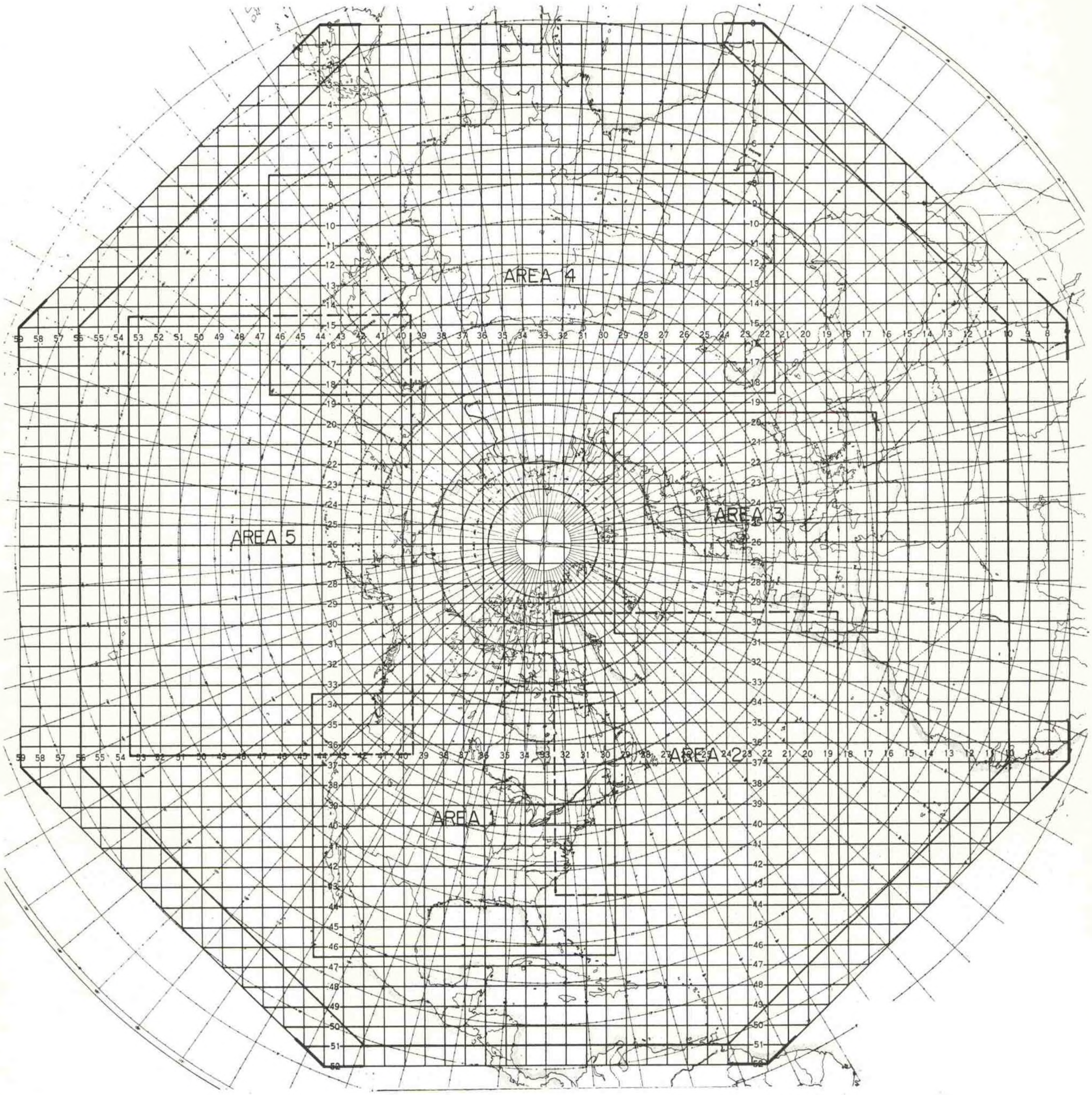
5. Donald E. Stoltz, Automated Analysis Branch, transferred to Sioux Falls, S. D., June 10, 1972.

6. Harold M. Hess, Basic Weather Forecast Branch, transferred to Weather Service Forecast Office, Washington, D.C., June 10, 1972.

IX. DISTRIBUTION OF PRODUCTS

As of June 30, 1972, NMC was originating about 810 separate teletypewriter bulletins each day for transmission over NWS, U.S. Navy, U.S. Air Force, and Air Transport Association teletypewriter service. The following table shows the additional NMC daily facsimile transmissions:

Recipient	Number of Transmissions
National Facsimile Network (NAFAX).................	98
Aviation Meteorological Facsimile Service (AMFAX)...	73
Navy Facsimile Network............................	18
Air Force Facsimile Network.......................	102
International Facsimile Network (Offenbach, Germany)	43
Russian Facsimile Network.........................	22
Forecast Office Facsimile Network (FOFAX):	
Circuit #10206................................	63
Circuit #10207................................	62
Circuit #10208................................	62
Caribbean Radio...................................	20
Tropical Analysis Network (TROPAN)................	43
Suitland-Honolulu Circuit.........................	67



Verification Areas