UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

NUMERICAL WEATHER PREDICTION

ACTIVITIES — 1975

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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1975

CONTENTS

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PART I SUMMARY OF MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 This report summarizes the 1975 activities in numerical weather prediction of the National Meteorological Center and, for the first time, the activities of the Techniques Development Laboratory of the National Weather Service of the USA.

1.2 This year was the twentieth anniversary of the installation and use of the first electronic computer in the USA for real-time numerical weather prediction. A few who were in the original staff took note of this milestone and the progress which has been made in operational numerical weather prediction during these past 20 years. The basic forecasting function of the National Weather Service has been significantly influenced over the years by this forecasting method,which originated in this early effort.

1.3 The following major events took place during 1975:

(a) The primary computer facility was upgraded by the acquisition of a third IBM 360/195 computer late in the year. The major organizational components of the National Oceanic and Atmospheric Administration, primarily the National Weather Service and the National Environmental Satellite Service, used the dual IBM 360/195 system for their operational requirements throughout most of the year. The processing of the meteorological data was done on the NMC system which consisted of three IBM 360/40's and one IBM 360/30.

(b) On May 21, 1975, the forecast period of the limited-area fine-mesh model (LFM) was extended from 24 hours to 36 hours for routine NWS use. The forecast superiority of this prediction system over the operational hemispheric system (6L PE) was especially apparent during 1975. On December 17, 1975, tests were initiated for the possible extension of the LFM runs to 48 hours.

(c) On November 4, 1975, the plotting of the North America surface charts was automated. The conventional plotting model was used, and the charts produced at eight observing times each day. Automation of the plotting on the Northern Hemisphere surface charts is planned for 1976.

(d) Automation of many of the charts for facsimile transmission was completed. Analyses and forecasts produced on the IBM 360/195's are now transferred directly onto the facsimile circuits without human intervention. The relatively few maps which are manually prepared in the World Weather Building are automatically digitized and transmitted into the computer system at Suitland for automatic transmission to the field forecaster.

(e) A ten-layer limited-area model designed for short-range hurricane forecasting was tested in near-real-time during the 1975 hurricane season.

(f) The first phase of the Data Systems Test (DST) was completed on the August and September data. The second phase will be conducted during January and February 1976. The DST is a USA test to ensure an early consideration of many of the problems to be confronted in the First GARP Global Experiment (FGGE).

(g) A physical oceanography group has been established within NMC. Project areas are: 1) numerical modeling of coastal circulation; 2) specification of meteorological forcing for coastal models; 3) objective analysis of sea surface temperature; and 4) wave refraction.

PART II RESEARCH AND DEVELOPMENT IN ANALYSIS-PREDICTION SYSTEMS (Development Division, National Meteorological Center)

2.1 Global Modeling Branch

2.1.1 Changes to FINAL 8-layer Global Model (8L GLOBAL (2.5°))

The major changes to the 8L GLOBAL (2.5°) run at FINAL time follow:

(a) 50-mb analyzed winds, rather than calm winds, are used as initial conditions in the "thetasphere"--the computational layer at the top of the model. The change was introduced on January 16, 1975. (Stackpole)

(b) The sigma-to-pressure coordinate transformation was substantially revised and the changes incorporated into the code May 28, 1975. (Stackpole)

(c) Efforts by F. Shuman have resulted in a changed design for the triangular tendency smoother. It is applied to the tendencies on the longitude-latitude grid and assures that the Courant-Frederichs-Lewy linear instability conditions are not violated. A slight departure from a precisely triangular shape has eliminated the possibility of a negative response for particular wave lengths. A theoretical method of specifying the quasi-triangle base-widths has been developed also. This resultant width is only slightly less than that which was previously computed experimentally. It is the smallest that can be used and satisfies the CFL stability requirements. This small width minimizes truncation error. This technique was introduced on May 28, 1975. (Stackpole)

(d) A full-latitude smoother, developed by F. Shuman and specifically designed for latitude-longitude grids, has been applied to the output fields of the 8L GLOBAL. This smoother maintains the same east-west resolution, as the meridians converge, as is maintained on the north-south direction. The smoother is full latitude [all-the-way-around] with a very sharp drop in response at the cutoff frequency. The smoothing is used for the output preparation of forecast maps. The technique was introduced on May 28, 1975. (Stackpole)

(e) An error was corrected in the calculation of pressure heights under the model terrain; the error, which did not affect the 1000-mb heights, caused the 850- and 700-mb heights to be too low by 30 or 40 meters. Since the 1000-mb heights were computed correctly, 850-1000 mb thicknesses, "under" mountains, were distorted. The correction was applied at those geographical points where the ground elevation is above the height of the 850- and 700-mb levels. This correction was introduced on August 12, 1975. (Stackpole)

(f) The Brown-Phillips energy-conserving form of the hydrostatic equation replaced the old method of calculating heights at sigma levels and of π in the layers. This form of the equation, plus the related specification of the value of the Exner function, $\pi = (p/1000)^{\kappa}$, at the "center" of the sigma layers, was coded by William Collins. Tests indicate a slightly better behavior of the total kinetic and potential energies. These modifications were incorporated into the operational 8-layer code on November 20, 1975. NMC Office Notes 92 (Brown) and 104 (Phillips) describe this form of the hydrostatic equation.
(Stackpole and Collins)

(g) The parameterization of subgrid-scale convective precipitation was incorporated into the model. This method of convective parameterization calculates the latent heat and precipitation contribution of subgrid-scale deep convection to the large-scale system. Eight-layer forecasts of conditionally unstable areas with favorable upward motion initiate the convective process. The subgrid storm extends vertically throughout the troposphere; the moist adiabat (from the lifted condensation level defined by air-parcel characteristics of the lowest model layer) prescribe temperature and moisture distributions. The storm wind has no vertical shear and is defined by a vertical mix of the large-scale profile. Storm upward motion is estimated from the existing large-scale convergence field; the extent to which the large-scale conditions depart from the ideal (for convective activity) determines the fractional area of the storm. This change was incorporated on December 10, 1975. (Hirano)

(h) Modifications to the large-scale precipitation method relax the former saturation-evaporation criterion. The former method required sufficient evaporation of rain as it fell through an unsaturated layer to bring that layer to saturation. The new model has a vertically varying condensation-precipitation criterion ($\leq$100% relative humidity) such that any moisture forecast in excess of the criterion in a model layer falls from that layer as rain. If this rain falls into the next lower layer and that layer is less than saturated with respect to a separate saturation-evaporation criterion, then enough rain will evaporate to bring that lower layer up to this separate saturation level. This modification was introduced on December 10, 1975. (Hirano)

(i) As a side effect of changes (f) and (g) above, the "moist convective adjustment" was deleted from the model on December 10, 1975.

(j) A difficulty with forecasts of longer than 2 days or so in the vicinity of the poles was alleviated by specifying (rather than forecasting) the polar values as the circumpolar average of the quantities at the adjacent row. This change was introduced on December 10, 1975.
(Stackpole)

2.1.2 Testing of 2.0° Hemispheric Version of 8-layer Model

Using the physical-numerical alterations detailed in 2.1.1, a weekly series of forecasts from the 8L HEM (2°) were implemented; these forecasts were extended to 84 hours. Depletions of mass in the top layer of the model at some grid points resulted in model failure. This problem was remedied by the use of a new upper boundary condition: a space and time constant pressure of 50 mb. (It should be noted that the 8L GLOBAL (2.5°) model, at FINAL time, still retains the layer of constant potential temperature as its upper boundary condition.) These tests also included a divergence damper, applied to the stratospheric winds, to control noise. (See 2.1.6.) The model uses a 7.5-minute timestep.

Each forecast was compared directly with its operational 6L PE counterpart. The Global Modeling Branch compiled standard statistical verification data for the 8L HEM (2°) as did the Data Assimilation Branch for the 6L PE, and the two sets of data were then compared. In addition a Forecast Division jury evaluated the 24-, 48-, and 84-hour forecasts subjectively. R. Hirano undertook the verification of the precipitation forecasts.

Four forecast cycles were completed by year's end and the program is projected to continue through March 1976.

2.1.3 Revisions of the Sigma-to-Pressure Coordinate Transformation in the 8L GLOBAL (2°) Model

In constructing mandatory-level parameters from the sigma-coordinate system, two methods are used: mandatory-level winds and temperatures are obtained by linear interpolations from sigma layers; mandatory-level heights are obtained by using the hydrostatic equation between sigma surfaces.

Until May 1975 the potential temperature and wind were assumed to vary linearly with the Exner function $\pi = (p/1000)^{\kappa}$; the mean of the values of π at the adjacent levels was assigned as the layer pressure. These assumptions introduced a substantial bias in the stratospheric heights and temperatures, a bias caused by the mechanics of the coordinate transformation and unrelated to the dynamics of the forecasting procedures.

A more accurate system was developed in which the temperature (not the potential temperature) is assumed to vary linearly with the natural logarithm of pressure; the layer quantities are assigned that value of pressure which relates to the potential temperature (θ) of the layer (a given quantity) and to the "thickness temperature" for the sigma layer. This "thickness temperature" (T) is determined by solving the hydrostatic equation $\partial gz/\partial \ell np = -$ RT for the sigma layer. Thus $\pi = T/\theta$ yields the p value.

This change, introduced into the output sections of the 8L GLOBAL (2.5°) on May 28, brought about a reduction in the stratospheric height and temperature biases. The tropospheric quantities were unaltered.
(Stackpole and Collins)

2.1.4 Global Model Noise Suppression

A series of experiments to test various techniques of suppressing noise in the global model were concluded. Two techniques provided improved noise control over the operational one which consists of a three-point time smoothing (used originally by Robert). One beneficial technique consisted of damping the vertical mean divergent wind component in layers above the material surface in the vicinity of the tropopause. The other method consisted of damping the mass-weighted vertical mean divergence in this same region of the model atmosphere. When damping the wind divergence throughout the entire atmosphere, precipitation was seriously depleted and anomalous flow was created over mountains.

An added advantage of these new techniques is that they permit a longer time step than did the time filter control. A 14% computer savings was realized. A report documenting these results is under preparation. (Dey)

2.1.5 Global Model Output Code

An output code has been written for the 8L GLOBAL. The program uses sigma layer data as input. Contour maps of a number of fields may be produced on any combination of three map projections: Northern and Southern Hemisphere polar stereographics; mercator tropical strips. The code may be used with any available latitude-longitude grid. (Dey)

2.1.6 Tropopause Experiments

The current method of calculating tropopause pressures for the 8-layer Flattery analysis had several deficiencies: errors in tropopause pressures; errors in heights and temperatures at mandatory pressure levels.

Tests replaced the upward-searching technique, used to locate the tropopause region, with a downward one. Results show a significant reduction in the RMS error of tropopause pressures. Verification of heights and temperatures at mandatory pressure levels, carried out after a pressure-sigma-pressure transformation, showed similar results.

Experiments are underway to determine how many layers are required to adequately define the vertical structure of the model atmosphere with and without the aid of a tropopause level. (Bostelman)

2.1.7 Spectral Modeling

Experiments with the complete spectral treatments of all spatial coordinates have not produced stable runs for periods of 48 hours with a twenty zonal modes resolution. However, an eight-wave truncation has been integrated satisfactorily.

It seemed reasonable to experiment with a vertical finite differencing scheme incorporating the conservation properties suggested independently by J. A. Brown and N. A. Phillips. To this end a second model version has been coded with satisfactory results up to 48 hours.

An interface program between the Hough-to-spherical-harmonic conversion and the spectral model is now being written to interpolate the mandatory level analysis into the sigma layers. In the process, it was found that with a choice of zero pressure at the model's top the hydrostatic diagnosis of temperatures produces highly unrealistic results. While a nonzero top pressure alleviates this problem, the resulting system of equations is not particularly suitable for a semi-implicit time integration. Consequently, the finite difference version of the vertically integrated hydrostatic equation was sacrificed--thus retaining the semi-implicit advantage. (Sela)

2.1.8 3L GLOBAL Forecast Model

Several major revisions have been made more recently in the 3L GLOBAL model and its allied programs. The initial data extraction program was modified to provide a more accurate return to the initial data (wind and height on pressure surfaces) from the model data (wind and temperature on sigma surfaces). The model itself was converted to three layers of equal pressure difference in the vertical and the Brown-Phillips energy-conserving scheme for calculating pressure force was incorporated.

The error in the global analysis program was eliminated in April 1975 and a new data set for late May 1975 was collected. A forecast to 4 days has been calculated from 0000 GMT May 22, 1975, initial analyses. Verifications were made over various regions of the globe with satisfactory results in all regions except in the tropical latitudes, where little or no forecast skill was found. The output and verification programs are being modified in preparation for calculation of experimental 3L GLOBAL model forecasts to 132 hours for evaluation for accuracy and value to NMC's extended forecast efforts. (Vanderman)

2.1.9 Momentum Flux from Mountain Gravity Waves

Work has continued, in Sweden, toward the development of a numerical model of gravity waves suitable for use within the framework of a NWP model. The equations of the wave model have been developed and sample calculations performed illustrating the potential utility of the model. (Collins)

2.1.10 Stochastic Dynamic and Monte Carlo Forecasting

Stochastic dynamic prediction is a technique whereby statistical hydrodynamical models are used to forecast directly mean and variance information of an evolving ensemble of atmospheric states. The mean provides the best estimate of the true state, in a least mean-square-error sense, while the predicted covariance information provides a quantitative estimate of the uncertainty in the forecast. The one disadvantage of the method which hampers its practical application is the rather large amount of computer time required. In order to alleviate this problem it may be possible to utilize a Monte Carlo approximation to the stochastic dynamic equations. Instead of forecasting the mean and covariance information directly, as is the case with the stochastic dynamic method, a relatively small number of solutions is run and the lowest order moments are estimated indirectly from this finite sample. Work is proceeding to test this hypothesis by making use of a simple barotropic model. Although the sample statistics are unbiased, they are nevertheless subject to sampling error in view of the limited sample size. Hence, one important question to be answered relates to the proper sample size which would provide stable statistical estimates. (Pitcher)

2.2 Regional Modeling Branch

2.2.1 General

Work on the semi-implicit and planetary boundary layer models, described in the 1974 Annual Report, was suspended due to higher priority tasks. Mr. Svante Bodin completed his visit in July and returned to the Swedish Meteorological and Hydrological Service.

Tasks of limited scope were completed: a test of the sensitivity of LFM forecasts to a data base which excluded observations above 200 mb; compilation of comparative humidity analyses with and without satellite VTPR relative humidity estimates; production of KCRT depictions of the LFM predicted stability index for use by the Severe Storms Forecast Center. (Gerrity)

2.2.2 Limited-area Fine-mesh Model (LFM)

During the first quarter of the year, the operational LFM forecast was extended from 24 to 36 hours. A detailed study of those cases in which the forecast failed to reach 36 hours resulted in changes in the model procedures that enabled the LFM to continue past the point of failure. In particular, model instability associated with the LFM boundaries was avoided by imposing a maximum allowable value on the magnitude of the wind components at each time step. In December, the routine LFM forecast was extended to 48 hours.

Earlier in the year, the noise level, when reviewed in the sigma domain of a routine LFM forecast, was quite high. Filters remove much of the noise after the sigma-level data are interpolated to constant-pressure levels in post processing; a noisy forecast, however, will contain spurious small-scale features in the sea level pressure or 500-mb absolute vorticity fields, for example, in the post-processed output.

Originally, the LFM forecast space-smoothed temperature and pressure at each time step but did not include the two outermost rows of the grid in the procedure. Consequently, noise from the boundary propagated into the interior. Recent smoothing modifications have included all interior grid points and, in addition to temperature and pressure, the horizontal wind components: changing the numerical value of a smoothing coefficient controls the noise level rather precisely; space filtering wind, temperature, and pressure largely obliterate the shortest wavelengths but leave the longest wavelengths relatively untouched. The new procedure reduces the noise-level significantly, and both the reliability and credibility of the model have improved.

In the belief that the model was overforecasting the areal extent of convective precipitation, the treatment of moist convective processes was examined. Although several variations in the computational method were tested, no definite conclusions were reached. The testing showed, however, that these calculations accounted for 20 percent of the total central-processing time of a forecast. Several cases were rerun and the convective processes computed only once an hour, rather than each time step (6 minutes). Little difference was noted in the precipitation forecasts, but the saving in computer time was significant. This change was incorporated in the operational LFM in November 1975.* (Newell)

2.2.3 Very-fine Mesh Model (VFM)

The VFM, a version of the LFM, employs a mesh-length one-half that of the LFM. Although this model covers one-quarter the area of the LFM, the VFM does encompass the 48 conterminous states and southern Canada. The grid length varies from 95 km at 60 degrees north to about 75 km at 30 degrees north.

One 24-hour forecast has been made using boundary conditions taken from a previously made LFM forecast. Possibly due to a mismatch between the pressure forecasts of the two models, difficulty in predicting the mass field was noted. A solution is being sought.

In connection with finer-mesh models, preliminary work has begun on a modified version of the LFM which will employ smaller mesh lengths than that of the operational version but cover the same geographical area. Both this model and the VFM should provide insight into the benefits of models of higher resolution. (Newell)

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*Verifications of LFM Operational Precipitation Forecasts may be found in Part VI, page 34.

2.2.4 LFM Boundary Condition Specification

The limited-area prediction model's atmosphere is coupled to the 6L PE atmosphere by time-dependent lateral boundary conditions. These conditions are extracted from the 6L PE model forecast made at the previous synoptic cycle. The models have similar vertical structures permitting the boundary conditions to be specified, directly, in terms of the sigma coordinate variables.

The planned implementation of the 8L HEM necessitates development of a different procedure because the sigma coordinate systems are incongruent. A new technique, to be tested early in 1976, converts the 8L HEM sigma-coordinate forecast data into isobaric data; this data is reconverted into the sigma system of the LFM. (Polger)

2.2.5 LFM Comparative Verification Statistics

Comparative verification statistics have been made between the LFM and the 6L PE. These data indicate that the LFM has a clear superiority at 500 mb, particularly at 36 hours. It is not clear, however, from the S1 scores that this is the case for the surface forecasts. There is evidence, however, that the LFM precipitation forecasts serve as better guidance for use by the NMC forecasters than the precipitation forecasts of the 6L PE.

During the latter part of December 1975, the LFM forecasts were extended to 48 hours on an experimental basis. Statistical evaluation of these forecasts will be compiled on a continuing basis through 1976.

The data presented in this section were provided by R. Van Haaren of Data Assimilation Branch. (Gerrity)

2.2.6 Hemispheric Nested Grid Model

This model has been brought to the state where introduction of real data can soon be started. Its format is flexible, not only in the number and location of the sigma surface but also in the number of interacting grids (1, 2, or 3) and their size, location, and orientation. Computation time estimates are of the order of an hour CPU time for a 24-hr forecast on the IBM 360/195 for a 6-level version in which the finest grid has an area about 2/3 the size of the present LFM grid but with twice the resolution. Two model features are of possible application to other NMC models. One is the development of a hemispheric orography grid which has been smoothed by a 72-wavenumber spherical harmonic filter. The other is the use of standard atmospheric height--a function of pressure--in place of log pressure or pressure to the 2/7 power as the vertical coordinate in interpolation between sigma and pressure coordinates. This has the advantage of exact reversibility in the sigma-pressure conversion for any temperature curve whose lapse rate is that of the standard atmosphere.

Current plans are first to run the model without physics on several real cases to verify its computational behavior. Physics will be added after this final stage (most likely a strict copy of the physics in present operational models). (Phillips, Campana, and Mathur)

2.2.7 Nested Grid Hurricane Model

Results from four numerical experiments using a four-level nested grid PE model designed to simulate the development of hurricane Isbell 1964 were compared. These experiments differed from each other either in the formulation of total latent heat release or surface friction. A cylindrical grid system (best suited to study dynamical structure of hurricanes) cannot be designed to have everywhere the same horizontal grid resolution as the Cartesian grid used in the model. It was found necessary, therefore, to calculate such terms as horizontal advection and pressure gradient at the Cartesian grid points first, and then interpolate to make the coordinate transformation at the cylindrical grid points. These results show that the asymmetric structure of surface winds ($\vec{V}_o$) is better simulated when the drag coefficient C_D is assumed to vary as $C_D = (0.7 + 0.7 \, |V_o|) \, 10^{-3}$ than when it is assumed a constant (value 0.0025). Surface friction tends to decelerate the inflow in the hurricane core region. The vertical motion at the top of the boundary layer (ω_B) may be visualized as associated with (1) the frictional convergence in the boundary layer, and (2) the strong zones of convergence induced in the boundary layer by the development of strong outflow regions in the upper troposphere. The latter contribution to ω_B is very large in the hurricane stage. The maximum winds in the boundary layer are located in the region of inflow, in contrast the maximum winds in the middle troposphere are supergradient and occur in the region of outflow. Some of these results were presented at the AMS Ninth Technical Conference on Hurricanes and Tropical Meteorology in May 1975 at Miami. (Mathur)

2.2.8 Air-Sea Interaction and Convective Parameterization

A new LFM test code modifies the LFM forecast code to replace the convective adjustment scheme with Kuo-type convective parameterizations. The code also incorporates four moisture levels (instead of the forecast code's three) plus the sea-to-air latent heat supply. Results suggest that Kuo-type parameterization leads to somewhat larger heating in the upper troposphere. Because of the vertical staggering of variables in the LFM, it is felt that warming in the upper troposphere may induce too much divergence in the model stratosphere with a resultant loss of stratospheric mass. Stratospheric "exhaustion" occurs more often with Kuo-type parameterization. (Mathur)

2.2.9 Experimental Forecasts--Hurricane Project

Five test cases with Hurricane Carmen early in the year showed surprising accuracy, yielding 36-hr forecasts of comparable accuracy to operational 24-hr predictions. Tests under semi-operational conditions during the summer and fall essentially confirmed the early performance levels and most forecasts were provided to the National Hurricane Center within the 12 hours of initial data time. The following table provides a breakdown of the number of prediction runs made for each storm:

Storm	Number of Runs
AMY	4
BLANCHE	3
CAROLINE	3
DORIS	0
ELOISE	12
FAYE	3
GLADYS	6
TOTAL	31

On the average, position accuracies under semi-operational conditions were not as outstanding as those produced for Carmen. This was to be expected as considerable testing was performed in the vicinity of high-speed jets. The paths of the storms continued to be predicted excellently; speed of movement, however, was poorly handled at times.

The major problem that surfaced during the year of testing involved the model's oversized initial vortex. This idealized storm is derived from a time integration of a two-dimensional prototype of the complete model. Lack of sufficient data in hurricanes has necessitated such an approach which guarantees a vortex in tune with the model equations but generally not a good reproduction of the atmospheric storm. The relatively coarse grid resolution forces the numerical storm to reach a horizontal extent larger than that generally observed and this in turn results in an erroneous northward movement. The problem becomes noticeable as the grid is positioned at latitudes below 20°N. Some temporary adjustments can be made to alleviate the problem during the coming year, but a complete solution can be achieved only by reduction of truncation error in the central portions of the grid.

Experimentation is continuing in order to better understand the hydrodynamic behavior of model storms as they move in simple flows, as well as those in the atmosphere. The vorticity budgets around moving storms are under investigation with primary interest focused on how the various terms in the vorticity equation are influenced by changing flow fields. The ageostrophic character of the forecasts have been evaluated in terms of storm movement as well. Simple, less expensive prototypes have proved to be valuable tools in these studies.

In preparation for the coming season, further optimization of machine codes has been carried out with reductions of approximately 10% in running time. Further time reductions involving data input into the model will be incorporated within the next few months.

Experimental forecasts have also been performed in non-hurricane situations with initial data interpolated from the NMC global operational analyses. The model has demonstrated a noticeable improvement over operational precipitation forecasts, showing in most cases better placement of large-scale features and an apparent ability to predict fine-scale features not resolvable on conventional grids.

(Hovermale, Scolnik, and Marks)

2.2.10 Isentropic Analyses--Hurricane Project

The isentropic analysis technique has been modified to obtain better vertical resolution (30 levels are treated rather than 10). This has placed more stringent requirements on data integrity and has increased the need for vertical consistency between levels. Considerable effort has been required to write programs to thoroughly check reports and to employ a variational technique that provides more vertical consistency in the final analyses.

A humidity analysis has been added to the package and evaluated in broad terms with fields obtained from the LFM. The codes appear to be functioning properly and further testing will require more objective standards.

The method includes an enhancement of boundary layer humidity fields through treatment of surface observations coupled with vertical gradients from radiosonde reports. Where radiosonde data is lacking, humidity estimates are inferred from local surface weather and cloud observations. These estimates, judiciously used, supplement the data employed in the overall humidity analysis.

An interpolation scheme which employs elliptic influence functions has been modified to make it applicable to moisture as well as wind analysis. The new version of the code, applicable to any size array, utilizes a "B-spline" under tension. It has been tested in analytic and real data cases with satisfactory results.

(Marks, Chu, and Jones)

2.3 Data Assimilation Branch

2.3.1 General

During this past year, the Branch was heavily involved in Data Systems Test (DST) activities for NASA. Conduct of impact tests and, to a lesser extent, efforts in data assimilation were limited until about November by extreme difficulty in obtaining turnaround for large computer jobs on the dual IBM 360/195 system. Archiving and impact tests were run with almost the entire DAB staff. A new effort began this year in forecast verification and model test and evaluation.

2.3.2 Data Archiving

Level II data sets were generated in real-time for the NASA Data Systems Test from 18 August through 18 October 1975. Types of data included and periods when these data were available are summarized in the following table:

Type of Observation	Period A 18 Aug-4 Sept	Period B 5 Sept-21 Sept	Period C 22 Sept-18 Oct
Surface observations	X	X	X
Radiosonde reports	X	X	X
NESS cloud-tracked winds	X	X	X
Wisconsin cloud-tracked winds	X	X	
Operational VTPR soundings	X	X	X
Nimbus 6 soundings	X		
Aircraft reports	X	X	X
Special aircraft reports	X	X	X
Constant-density balloon (TWERLE) data	X	X	X

Average daily collections during Period A include about 6000 satellite temperature soundings and 5000 cloud-tracked winds. Data tapes for this period were mailed to Goddard Institute for Space Studies (GISS), the National Center for Atmospheric Research (NCAR), the Geophysical Fluid Dynamics Laboratory (GFDL), Professor Arakawa at UCLA, and the Bureau of Meteorology, Australia. (Desmarais, Chiusano, and O'Neil)

Global analyses were produced from Period A Level II data sets using the 8L GLOBAL (2.5^{o}) and the Flattery spectral analysis scheme. Analyses were produced twice daily with a 12-hr analysis-forecast cycle. Tapes containing analyzed values of height, temperature, moisture and wind (Level III data sets) were mailed to GISS, GFDL, NCAR and UCLA for use in GARP-related experiments. (Desmarais, O'Neil, and Bonner)

2.3.3 Data Impact Tests

(a) A very limited test was conducted in which VTPR soundings derived at GISS were used in the NMC global analysis-forecast system. GISS soundings were produced at 2.5° latitude-longitude intersections (grid points of this global model) from radiance measurements supplied by NESS and the NMC global 12-hr forecast temperature profiles. Analyses were produced from 12 GMT 4 February to 00 GMT 9 February 1975--using the normal NMC data base, except that GISS VTPR soundings replaced the operational retrievals. GISS soundings were given the same weight as radiosonde data; resulting analyses were excessively noisy and showed small-scale features that were not realistic. Height fields at 1000 mb and temperatures aloft were frequently inconsistent--at least partly because the GISS soundings were provided to us with 1000-mb heights that were actually 12-hr forecasts from our analysis-forecast cycle. Further tests of "high density" retrievals will be conducted using Nimbus 6 data. (Desmarais and Bonner)

(b) A fairly extensive test of the impact of satellite temperature soundings was conducted using DST data sets collected in August and September (see previous section). DST Level III analyses were compared with analyses produced by a parallel system using the same data base but with satellite soundings (VTPR and Nimbus 6) removed. A series of 84-hr 6L PE forecasts were made from DST and parallel mode analyses on 10 forecast days. Results showed, once again, little or no improvement in forecast skill from use of satellite temperatures.
(O'Neil, Bonner, and Desmarais)

A third analysis-forecast cycle, run for only 5 days, used the full DST data set with radiosonde observations removed. Temperatures aloft were provided only by satellite soundings. Analyses generated in this mode agreed in all major features with the operational NMC analyses on corresponding days; however, as in an earlier experiment, the analyses contained systematic underestimates of the intensities of major systems and the strength of the wind. At least some of this underestimation is to be expected from use of asynoptic data in a 12-hr forecast cycle. (Bonner, Desmarais, and O'Neil)

A condensed version of the NASA Study Report describing the VTPR impact test (see NWP Activities Report 1973) was submitted for publication as a NOAA Technical Memorandum.
(Bonner, O'Neil, Desmarais, Van Haaren, and Lemar)

An article describing the ITPR impact test (see NWP Activities Report 1974) has been submitted for publication as a NOAA Technical Memorandum. (Bonner, Van Haaren, and Hayden (NESS))

(c) Temperature and moisture data from Nimbus 6 are being evaluated through construction of cross-sections and constant-pressure analyses in a series of case studies from the August-September DST period. (Tracton)

(d) Fairly extensive comparisons are being made between rawinsonde reports and co-located mid- and high-level satellite winds generated by the University of Wisconsin during the August-September DST. Results of an earlier, similar study (see NWP Activities Report 1974) were documented in NMC Office Note 114. (Lemar)

2.3.4 Model Test and Evaluation

Work was begun on the development of a standard verification package for routine, operational evaluation of the LFM, 6L PE, and 8-layer model forecasts. Specialized verification and diagnostic routines are being developed for evaluation of the ability of NMC models to forecast cyclogenesis. As DST activities subside, the Branch will assume major responsibility for model evaluation within NMC.

(Van Haaren, Tracton, and O'Neil)

2.3.5 Data Assimilation

Two parallel experimental global assimilation systems based on different horizontal resolutions of the NMC 8L GLOBAL are being tested. The goal of this effort is to develop an assimilation system capable of being used operationally during the First GARP Global Experiment (FGGE).

(a) System I. This system involves simply a reduction of the NMC FINAL 12-hr global analysis-forecast cycle to a 6-hr cycle in which data are treated as synoptic within a window of ± 3 hrs. A parallel test of 6- and 12-hr cycles with the spectral analysis scheme and 8L GLOBAL (2.5^{o}) model conducted during 1975 revealed numerous problems with the 6-hr cycle. Most of these problems were related to the accumulation of noise in the system. Apparently, 6 hours is not sufficient time to dissipate the "shock" introduced by the analysis procedure and the transformation from p to σ coordinates. Efforts are underway to overcome this problem. (Desmarais, Rasch, and McPherson)

A series of sensitivity experiments are being conducted to produce a better understanding of the characteristics of the spectral analysis scheme. Particular attention is being given to the relationship between winds and heights and to the manner in which single level reports influence analyses at other levels. A report is being prepared describing the results of these experiments. Several memos were written describing various features of the spectral analysis scheme. These memos are the first step in preparation of a report documenting the overall features of the analysis code. (Rasch)

On August 7, 1975, blending of height and wind analysis coefficients was eliminated from the FINAL analysis. This was done to eliminate unrealistic warming near the poles and cooling near the Equator in the stratosphere, which results from not including the cyclostrophic component in the wind law which is enforced by the blending. However, large ageostrophy can exist now in data-void areas of the analysis. Experimentation is now underway to re-introduce the blending with the cyclostrophic effect included.

(Parrish (Automation Division))

(b) System II. The second system differed from the first primarily in that updating of the prediction model was done by means of a <u>local</u> interpolation method, affecting only grid points in the vicinity of observations. In addition to reducing the shock of data insertion and thus the cumulative noise level, this also permits greater flexibility in treating observations of nonhomogeneous quality and characteristics. System II will ultimately use a multivariate three-dimensional optimum interpolation procedure.

In the prototype constructed during 1975, however, a two-dimensional Cressman-type analysis of temperature and surface pressure was used to update the 5^{o} version of the NMC 8L Global model (8L GLOBAL (5^{o})). Preliminary comparative tests of both systems have shown that local updating results in a smaller shock following data insertion than was evident in System I. Testing of both systems (using 5^{o} resolution) will continue. (Kistler, Gordon, and McPherson)

An optimum interpolation analysis program for surface pressure was developed and tested. The analysis results compare favorably with analyses produced by the Cressman and Flattery methods.

(Bergman and Kistler)

A single grid point version of the multivariate optimum interpolation code was written and is now ready for testing with artificial data. Some modifications to the analysis system as originally described in Office Note 116 were made. These include a revised treatment of the polar-latitude forms of the analysis equations, the use of a latitudinally varying function to decouple the cross-correlations between temperatures and winds, and a change in the vertical correlation functions used in the wind component analyses. A univariate analysis of dew-point depression and an error-checking routine which utilizes optimum interpolation will be included in the final analysis package. (Bergman and Gordon)

Forecast error covariances and correlations required by the optimum interpolation scheme were computed for 12 mandatory pressure levels using worldwide rawinsonde data from 10 randomly selected synoptic times. Results of these computations suggest the change in the vertical correlation functions mentioned above. Horizontal and cross-correlations will be computed using the same rawinsonde data base. (Gordon and Bergman)

2.3.6 Related Projects

(a) A paper "Analysis Error as a Function of Observation Density for Satellite Temperature Soundings with Spatially Correlated Errors," originally issued as Office Note 119, has been revised and submitted to the Journal of Applied Meteorology for publication. The revised paper includes a tentative error correlation function for neighboring satellite temperature observations. This function was obtained for a limited data sample by comparing Nimbus satellite temperatures with cross-section analyses based on rawinsonde data.
(Bergman, Bonner, Lemar, and Van Haaren)

(b) An examination of the information content of VTPR retrievals was carried out during 1975. In this study, co-located VTPR and radiosonde temperature and thickness profiles were fit by squares to appropriate sets of empirical orthogonal functions. RMS differences were computed as a function of the number of empirical functions used to represent the profiles. It was found that reducing the number of functions from 12 (perfect fit) to 5 resulted in only a slight decrease in the RMS difference. Thus, it appears that most of the RMS difference of 2 to 3 degrees between co-located VTPR and radiosonde reports is associated not with differences in the vertical resolution of the two sounding systems but with variations in "true" temperature between "co-located" reports and with large-scale vertical bias in the VTPR retrievals. (McPherson and Gordon)

(c) Documentation of a series of experiments performed in 1974 investigating the performance of various insertion techniques within the content of a primitive-equation barotropic model was completed during 1975. A geostrophic correction to the motion field based on observations of the mass field was reported in a paper entitled "On the Use of a Local Wind Correction Technique in Four-Dimensional Assimilation" (Kistler and McPherson, MWR, 103, No. 5). Characteristics of several damping time integration methods and their application to data assimilation were examined in NOAA Technical Memorandum NWS NMC-56 (McPherson and Kistler). Finally, NMC Office Note 106 describes experiments in which data sets were inserted repeatedly in an effort to improve the assimilation of the data.

(McPherson and Kistler)

(d) A review paper entitled "Progress, Problems, and Prospects in Meteorological Data Assimilation," was published in the November issue of the Bulletin of the American Meteorological Society.

(McPherson)

2.4 Upper Air Branch

2.4.1 Analyses of Stratospheric Data

(a) Revision of stratospheric analysis program (70-10 mb). After studies were made of satellite data in comparison with neighboring radiosonde data, the analysis code was revised to permit the analysis of VTPR height and temperature data at selected levels. Beginning on July 22, 1975, satellite data were included operationally at all four analysis levels, though heavy smoothing and tight scan-limits somewhat limited their overall effect. Later on, the VTPR data were removed from the original (daily) version of the analysis program to maintain consistency with the NMC FINAL analysis during the DST period. (A further consideration was the increasing incompatibility between VTPR and radiosonde data as winter approached.) New program changes (12/18) included adjusting height and wind weighting, tuning toss-out limits (especially at low latitudes), and replacing heavy smoothing with a 9-point filter. Results revealed better RMS fit of analysis to data, and exposed problems with regressions and data-handling.

(Laver and Finger)

(b) Rocketsonde-satellite comparisons. United States rocket stations have been scheduling meteorological rocketsonde launches to coincide with NOAA and Nimbus satellite overpasses. The radiances computed from the rocketsonde-radiosonde temperature profiles are compared with the satellite radiance measurements in the tropospheric and stratospheric channels. Results from comparisons for NOAA 3 and NOAA 4 VTPR data have indicated a correlation between biases in the radiance measurements and biases in temperature retrievals from 1000 to 10 mb. The National Environmental Satellite Service has switched to a system of regression retrievals (based on coincident radiosonde observations) to minimize the effects of biased differences from radiosonde measurements.

Rocketsonde comparisons with Nimbus 6 sounders (HIRS, LRIR, and PMR) launched in June 1975 have begun. These comparisons will be especially useful for determining the compatibility of the various stratospheric and mesospheric sounders. (Gelman, Miller, and Finger)

(c) International rocketsonde comparisons. Comparisons were made of the temperature and wind information obtained from the rocketsonde systems of France, Japan, the United Kingdom, the Union of Soviet Socialist Republics, and the United States. Evaluation of the results allowed adjustments to be derived, leading to more meaningful use of the data for depicting stratospheric-mesospheric circulation. A paper describing the results was published in the _Journal of the Atmospheric Sciences_, September 1975. (Finger and Gelman)

(d) Rocketsonde data-exchange and analysis. Rocketsonde data are used on a continuing basis in weekly meridional cross-sections from 20 to 70 km. These analyses are being exchanged with the Soviet Union under a bilateral agreement for cooperation in space research.
(Finger, Gelman, McInturff, and Nagatani)

(e) Evaluation of satellite data. Mapped fields of VTPR stratospheric channel radiation data were monitored, and feedback provided to NESS on instrumental irregularities. Scan-bias problems in retrieval temperatures at 10 mb were reported, resulting in regression modifications by NESS. Preliminary comparisons were made of HIRS-derived stratospheric temperatures with independent data. Evaluation of British PMR radiation fields has been initiated.
(Quiroz, Gelman, and Nagatani)

(f) Falling-sphere soundings. Report on reliability of temperatures from sphere drag soundings, needed for checkout of new satellite instruments (PMR, LRIR) has been completed; to be published in _Journal of Geophysical Research_. (Quiroz and Gelman)

(g) SST forecasts. Reevaluation of NMC's 100-mb and 70-mb forecasts (SST flight levels) is tentatively planned for the winter of 1975-76, using latest version of the NMC 8-layer Global Model. (Laver, Nagatani, and McInturff)

(h) Comparison of Flattery spectral and Cressman-type analysis in stratosphere. Preliminary comparisons of these two systems at 70 and 50 mb were begun. Estimates are being made of accuracy, effects of VTPR data, and feasibility of using the spectral analysis system at stratospheric levels. (Myers and Laver)

2.4.2 Research on Atmospheric Circulation

(a) Stratospheric warmings and polar vortex breakdown. Papers on (1) evolution of warmings, based on analysis of satellite radiation data, and (2) comparative features of warmings, simulated and observed, were published in the Journal of Atmospheric Sciences. Wintertime disturbances of Northern and Southern Hemisphere stratospheres were continuously monitored. Analysis of radiation fields, construction of circulation maps, investigation of relevant tropospheric parameters, etc., were conducted. (Quiroz, Miller, Nagatani, and others)

(b) Stratospheric warmings and tropospheric blocking. Preliminary efforts are being made to correlate stratospheric warming trends with tropospheric blocking. Height anomaly patterns are being studied during periods of stratospheric warming activity. (Myers, Laver, and Finger)

(c) Global energy program. The program for computing several terms of the global energy balance has attained operational status. In addition, the program is being run off the 6L PE forecasts at 00, 12, 24, 36, 60, and 84 hours, and it is planned to evaluate the 8-layer global forecasts in a similar manner. (Miller, Collins of Global Mod. Br.)

(d) STRATWARM monograph. An assessment is being undertaken of current knowledge of the stratospheric-warming phenomenon. It takes the form of a complete description from the synoptic, dynamic, and energetic points of view. Particular attention is given to interactions between the stratosphere and troposphere, and between the stratosphere and mesosphere. First-drafts of all chapters have been completed. (Upper Air Branch Staff)

PART III TECHNIQUES DEVELOPMENT AND APPLICATION OF NEW PRODUCTS (Systems Development Office, Techniques Development Laboratory)

3.1 General Development Techniques

The forecast research program of the Techniques Development Laboratory (TDL) is divided into public weather prediction, severe local storm prediction, marine environmental prediction, terminal weather prediction, and AFOS* forecast applications. In each of these main areas, the principal goals are to develop better objective methods for making weather forecasts and to provide for their implementation at the appropriate place in NWS.

In order to accomplish these goals, TDL collects extensive samples of forecasts from operational numerical models and statistically relates weather variables such as temperature, winds, precipitation, and occurrence of thunderstorms to these forecasts. This technique is called Model Output Statistics (MOS). New numerical models are also developed when the need arises. For instance, a comprehensive model of the boundary layer is being built which will soon fill a gap in the spectrum of NWS models. Initialization for numerical models requires intensive study of analysis methods like successive approximation, optimum interpolation, and variational adjustment.

AFOS will provide a new dimension to the use of automated techniques. For the first time, communication, computer, and display facilities will exist at a station, which will allow rapid response to urgent queries by forecasters. For instance, a forecast of precipitation can be updated very quickly based on recent radar data. Consequently, some of TDL's techniques are being tailored for use on the minicomputers.
(Klein)

3.1.1 Public Weather Prediction. Much emphasis is being placed on developing new and improved automated predictions of all weather elements contained in public weather forecasts. Efforts are focused on the four key meteorological elements: precipitation, temperature, clouds, and wind.
(Glahn)

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*Automation of Field Operations and Services.

3.1.1.1 Precipitation forecasting. The automated system that produces nationwide forecasts of conditional probability of frozen precipitation (PoF) underwent extensive verification and additional study during 1975. New equations based on additional data were derived for use during the 1975-76 winter. TDL completed an experiment in which forecasts from an experimental PoF system developed with the regression estimation of event probability (REEP) techniques were compared with operational PoF forecasts made with the logit model. The results indicated that the logit model should continue to be used in the operational system.
(Bocchieri and Gilhousen)

Quantitative precipitation forecasts (QPF) made from regionalized equations were supplied to NMC. Previously, only one equation for the coterminous United States was used. For the winter season of 1974-75, six regions were used. Also, categorical forecasts of precipitation amount are now being computed from the probability forecasts in such a way as to maximize the threat score, a statistic used at NMC for verifying forecasts of precipitation amount.
(Bermowitz and Zurndorfer)

3.1.1.2 Surface temperature forecasting. During 1975, TDL continued to monitor and improve the MOS temperature guidance. The MOS system forecasts maximum and minimum temperatures for 228 stations in the conterminous United States. These forecasts, prepared after 0000 GMT and 1200 GMT, use predictors from both the PE and trajectory models.

In July, a new series of summer regression equations based on 5 years of data were implemented. These equations are for a shorter season than used previously. A larger number of potential predictors were also provided to the screening program. Recent verification has shown that use of the shorter season, additional dependent data, and the added predictors improved the MOS forecasts. TDL intends to derive sets of operational equations for each of the four 3-month seasons.
(Hammons and Dallavalle)

3.1.1.3 Cloud forecasting. During the past year, TDL developed and implemented a system to forecast cloud amount. Automated MOS forecasts for 233 stations are now on teletypewriter on a request basis. Probabilities of clear, scattered, broken, and overcast, and a single "best" category are produced for each of seven projections (12-48 hr). The input data for these forecasts are from NMC's PE model and TDL's trajectory model. Separate summer (April-September) and winter (October-March) season forecast equations are available for each station.
(Carter)

3.1.1.4 Surface wind forecasting. TDL derived a new set of surface wind forecasting equations for the summer season. Several improvements were made, including increasing the dependent data sample, adding new predictors, increasing the number of terms per equation, and removing the forcing constraint on the first three predictors. In order to reduce the tendency of the regression equations to underforecast strong winds, a technique called inflation is now being used. This causes the variability of the forecasts to be about equal to the variability of the verifying observations. These changes should improve the overall performance of the automated wind forecasts.
(Carter)

3.1.2 Severe local storms. One of the major research efforts in TDL is addressed to the development of automated techniques for forecasting severe local convective weather, notably thunderstorms and their manifestations like hail, strong wind gusts, and tornadoes. The forecasts cover three time ranges: 6-24 hr (medium range), 2-6 hr (short range), and 0-2 hr (very short range). Another task, having a direct bearing on both the short- and medium-range tasks, aims at developing a predictive numerical model of the planetary boundary layer.
(Alaka)

3.1.2.1 Medium-range forecasting. In the area of medium-range forecasting, TDL has developed new multiple regression equations to predict the probability of both general and severe thunderstorms 24 hours in advance. The equations were obtained by relating MOS predictors to manually digitized radar (MDR) data and severe storm reports. MDR data are coded for blocks 40-45 miles on a side. Thunderstorm and severe storm probabilities are forecast for each block in the MDR grid array. The forecasts are valid for a 6-hr period centered at 0000 GMT. The predictand for the general thunderstorm equation was based solely on MDR intensity values. Different equations were developed for the spring and summer seasons. The predictand for the severe storm equations was based on both MDR data and severe storm reports. The forecast probabilities for the MDR grid area are transmitted by facsimile to field offices of NWS, including NSSFC in Kansas City.

Additional efforts in the medium-range task include improvements to the TDL trajectory model to provide more accurate forecasts for use in severe storm prediction. One improvement involves the simulation of the thermal interaction between the earth's surface and the predictand air parcel trajectories over land.
(Reap, Kemper, and Foster)

3.1.2.2 Short-range forecasting. The aim of this task is to develop objective techniques for making 2-6 hr forecasts of both severe local weather and general thunderstorm occurrences. Equations for making these forecasts were developed by multiple screening regression, the independent variables being selected from a set of 26 diagnostic quantities derived from hourly surface observations and 500-mb temperature forecasts obtained from NMC's LFM model. For the 1975 storm season, TDL developed and implemented new regression equations based on a larger data sample. (Charba)

3.1.2.3 Very short-range forecasting. Effort in this range (0-2 hr) relies on the capability of weather radar to identify and trace the development of severe local storms. Basic data consists of radar reflectivities conveniently digitized into nine intensity levels. The goal is to develop computer programs which will identify, track, and extrapolate positions of these echoes. Three echo-tracking techniques of different complexity are being investigated. The input data to these techniques consist of zero degree radar reflectivities and patterns of vertically integrated liquid water content (VIL). (Elvander)

3.1.2.4 Boundary-layer model. Since severe local storms are strongly influenced by conditions in the lower atmosphere, TDL is developing a three-dimensional boundary layer model (BLM) to aid in severe storm prediction. This model will forecast wind, temperature, and humidity in the atmosphere's lowest 2 km. Initially, forecasts will be for the portion of the United States east of the Rocky Mountains. The grid spacing over this area is roughly 80 km. In the vertical, eight levels with separation increasing with elevation are planned.

Particular attention is being focused on the surface and the atmosphere's lowest 50 m. At the surface, the model predicts temperature and humidity using an energy balance. Latent, sensible, and soil heat fluxes are constrained to equal the net radiation. Soil moisture for the model will be updated daily by measured rainfall. Also, measured surface temperatures will influence the model's initial soil temperature. Wind and temperature profiles in the lowest 50 m depend on the atmospheric stability in that layer and on surface roughness. (Shaffer, Yu, and Kemper)

3.1.3 Marine environmental prediction. In the area of marine environmental prediction, TDL has continued working to develop techniques for forecasting the state of the marine environment in the oceanic, coastal, and Great Lakes area. (Pore)

3.1.3.1 Oceanic forecasting. Since 1968, TDL has produced automated wave forecasts twice daily for projections out to 48 hr for the North Atlantic and North Pacific Oceans. These wave forecasts are based on the output from NMC's PE model. In 1975, these programs were converted for use on NOAA's IBM 360/195 computer. (Pore and Richardson)

3.1.3.2 Coastal forecasting. TDL implemented an automated method to forecast surface wind at eight offshore light stations along the east coast. The MOS technique was used to produce regression equations from 3 years of light station observations and PE forecasts. Different forecast equations were derived for the summer and winter seasons and for each of the two daily forecast times of 0000 GMT and 1200 GMT. The model forecasts to 42 hr in advance at 6-hr intervals. (Feit)

Both versions of the SPLASH (Special Programs to List Amplitudes of Surges for Hurricanes) program--SPLASH I for landfalling storms and SPLASH II for storms of general motion--were released to the National Hurricane Center for operational use on the IBM 360/195 system. A significant improvement was made in these programs in FY 1975 with the derivation of a sheared coordinate system. This system accounts for curvature of the coastline if the curvature is not too drastic. A version of SPLASH with the sheared coordinate system will eventually replace SPLASH II for operational use.

(Jelesnianski, Barrientos, and Chin)

3.1.3.3 Great Lakes forecasting. TDL continued to produce operational wind forecasts for all five Great Lakes. The lakes are divided into 12 forecast areas for this purpose. Wind forecasts are produced to 36 hr with forecast equations based on the MOS system. Input to the forecast equations are numerical weather predictions from the PE model of NMC. During 1974, TDL began work on an automated wave forecast system that uses these objective wind forecasts as meteorological input. The preliminary version of the model was completed and put into operational use in January 1975. Modifications to the Bretschneider wave-forecast method and Saville method of fetch length correction for limited fetch width are being used. Forecasts are made twice daily for 64 points and are transmitted via teletypewriter. (Feit and Pore)

Work has begun on a two-phase effort to improve the objective forecasts of mesometeorological phenomena in the Great Lakes region. In the first phase, an objective technique to analyze the 3-dimensional atmospheric structure around and over the lakes is being developed. This technique is based on a numerical variational analysis scheme that links surface and upper air observations with the atmospheric dynamics to arrive at a mesoscale picture of the Lakes region. In the second phase, statistical, short-range (6-12 hr) forecast equations using the analyzed parameters as predictors will be developed. The forecast equations will predict such phenomena as low-level winds, temperatures, cloud conditions, and lake-effect snowstorms. (Grayson)

3.1.4 Terminal weather prediction. With the cooperation of the U.S. Air Force, TDL began operational production of objective medium-range terminal forecasts. Two types of products are produced: three-category combined ceiling and visibility probability forecasts, and five-category ceiling and five-category visibility probability forecasts.

TDL developed the prediction equations for both types of forecasts through use of the MOS system; equations use predictors from the PE and trajectory models, and surface observations 6 hr after model run time. The three-category equations were developed with the single-station approach; the regionalized approach was used to develop the five-category equations for 14 regions covering the coterminous United States. (Crisci, Globokar, and Hebenstreit)

3.1.5 AFOS forecast applications. During 1975 TDL had three active tasks: the automatic monitoring and updating of aviation terminal weather forecasts, the generation of computer-worded public forecasts, and the updating of probability of precipitation (PoP) forecasts. (Lowry)

3.1.5.1 Aviation monitoring and updating. This task aims at monitoring forecasts and updating guidance as needed. The goal is to develop a system which will automatically monitor aviation terminal forecasts to insure their validity and representativeness. This will be accomplished with AFOS minicomputer software that will compare each observation of ceiling and visibility at a terminal with its forecast and determine if a problem exists. If a problem does exist, the system will advise the forecaster of the circumstances with a terminal alerting procedure (TAP) message. The TAP message will also provide a guidance forecast to help in preparing a new official terminal forecast.

In 1975, development of the needed software began. Single-station prediction equations were developed which will be used to generate the guidance forecasts contained in the TAP message. The equations are for six categories of ceiling and visibility for projections of 1, 2, 3, 4, and 6 hr. (Crisci)

3.1.5.2 Computer-worded forecasts. The purpose of this task is to prepare a worded forecast message, entirely by computer, which is in the same form as the final product. MOS forecasts of several weather elements are input to the computer program. The program is running in a test mode once daily. Such a forecast should be a good starting point for the forecaster in preparing his public weather forecast. If he finds no reason to alter the forecast, he can merely push a button on the AFOS console and the dissemination will be automatic. Likewise, he can make a slight alteration or even change the forecast completely. The former he can do by simple text editing; the latter by entering a new set of forecast values and instructing the computer to generate a new worded forecast. (Glahn)

3.1.5.3 PoP updating. TDL started this task in 1975; it is aimed at updating PoP guidance. The plan is to use MDR reports in a scheme that leads to update PoP forecasts for the near future. MDR data provide frequent information concerning rainfall on a subsynoptic scale. The current guidance product, based on PE model runs from 0000 and 1200 GMT data respectively, is available by 0700 and 1900 GMT. MDR data are available hourly for use prior to the forecast release time. Two efforts are underway; one under contract and one in-house.

The contract effort uses MDR data at two times, 2 hr apart, in order to identify and track echo groups. The movement of these groups is then extrapolated several hours into the future. Information like the time it takes an echo group to pass by a station and the maximum intensity of that group is being recorded for regression analysis. The in-house effort also used MDR data but in a different way. Backward trajectories are constructed from observing stations by using an advecting wind derived from PE forecasts. The radar information is then saved from the point of origin as determined by the trajectory. These data are being used as predictors for regression analysis. (Gilhousen)

PART IV ANALYSIS-FORECAST SYSTEMS IN OPERATIONAL USE IN 1975

4.1 The basic operational numerical weather prediction system remained unchanged during 1975. The four basic cycles, RADAT, LFM, OPERATIONAL and FINAL, were run from the 0000 and 1200 GMT data times daily. These are summarized below:

RADAT - This is a quick-look forecast initiated 1 hour and 30 minutes after data time. It consists of the Flattery spectral analysis and the filtered barotropic model forecast with long-wave stabilization control. The nonlinear balance equation was used in the initialization. Terrain and friction effects were incorporated through the use of an 850-500 mb thickness forecast made simultaneously. 500-mb forecasts were made to 48 hours on the 1977-point stereographic 381-km grid.

LFM - This cycle began approximately 2 hours after observation time and was basically the same as was run in 1974. The major exception to this was the change in the forecast length from 24 hours to 36 hours. The model changes which were implemented are described under the Regional Modeling Branch activities in Part II of this report. The analysis method was a successive correction technique and the forecast model was basically the 6-layer Shuman-Hovermale system on a 53 x 45 horizontal grid on a polar stereographic projection true at 60°N. The grid distance was 190.5 km at 60°N and the time step was 6 minutes.

OPERATIONAL - This cycle was initiated 3 hours and 20 minutes after observation time. No significant change was made in it during 1975. It consisted of the Flattery spectral analysis technique and the 6-layer Shuman-Hovermale model (6L PE). The forecast grid was a 65 x 65 domain covering the Northern Hemisphere with a 381-km grid distance. The time step was 10 minutes. Forecasts were made to 48 hours from the 1200 GMT data and to 84 hours from the 0000 GMT data. The barotropic model was used to extend the forecasts to 96 hours at 1200 GMT and 156 hours at 0000 GMT. As in 1974, the Reed model (1963, NMC Technical Memorandum NWS NMC-26) was used to produce a 1000-500 mb thickness prediction from 84 to 156 hours at the 0000 GMT time.

About 5 hours and 30 minutes after observation time, a Trajectory Model designed by the Techniques Development Laboratory (NWS Technical Procedures Bulletin No. 97, September 1973) was run using 6L PE forecast parameters. Model Output Statistics (Klein and Glahn, Bulletin of the American Meteorological Society, Vol. 55, No. 10, October 1974) were obtained using predictors from the 6L PE and the

Trajectory Model. Short-range predictions were obtained for maximum and minimum temperatures, probabilities of precipitation, quantitative precipitation amounts, cloud amounts, ceilings and surface visibilities and winds, and probabilities of thunderstorms and severe weather for several hundred United States and a few Canadian stations. For marine requirements, forecasts were also made for surface wave and swell conditions for the North Atlantic and North Pacific Oceans and for storm surges along the east coast of the United States and the Great Lakes.

FINAL - In order to bring late arriving data into the numerical system, a FINAL cycle was initiated 10 hours after observation time. The data were analyzed with the Flattery analysis program, and a 12-hour forecast was obtained with the Stackpole 8-layer global model on a 2½ latitude-longitude grid (8L GLOBAL (2.5°)). This was then used as the first guess of the analyses at the next RADAT, OPERATIONAL, and FINAL cycles.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS

5.1 A major change is planned in the numerical guidance cycles in order to make the LFM products available to the field forecasters at an earlier time. During 1976 it is planned to have the teletype transmission of the United States upper air observations (Part A) completed in time to initiate the LFM cycle 1 hour and 40 minutes after observation times. The forecast period of this model will be extended from 36 to 48 hours. Forecasts using Model Output Statistics will be made in which the 6L PE and the LFM parameters are used as predictors. These changes will require further changes to be made in the RADAT cycle, the alternative to which has not yet been decided.

5.2 Present plans are to replace the 6L PE in the OPERATIONAL cycle with a hemispheric version of Stackpole's 8-layer model on a 2^{o} latitude-longitude grid (8L HEM (2^{o})). The final design of the system will depend on the results of extensive testing in 1976.

VI. FORECAST VERIFICATIONS--MONTHLY MEANS FOR 1975

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	58.5	12.1	81.7	15.3	.79	68.3	13.9	101.5	17.5				.75	85.4	15.5	111.6	18.0
Mar.	.82	49.1	11.1	78.7	15.5	.83	61.3	13.0	100.6	18.0				.81	72.0	14.6	111.3	19.0
May	.78	43.6	10.2	65.5	13.7	.79	54.6	11.8	85.1	16.2				.79	62.2	12.8	95.1	17.3
July	.72	40.5	9.3	55.5	12.0	.75	49.4	10.4	71.3	14.1				.74	58.5	11.5	79.3	15.3
Sep.	.81	42.1	9.6	69.2	13.4	.82	52.7	10.9	38.7	15.8				.78	66.8	12.3	99.7	17.2
Nov.	.85	49.4	10.3	89.6	16.0	.85	61.3	12.1	115.2	19.2				.82	77.4	13.9	129.9	20.7
300 mb																		
Jan.	.80	57.3	11.4	90.5	17.1	.82	67.4	13.3	109.5	19.2				.78	82.3	14.9	118.9	19.8
Mar.	.85	49.4	10.7	91.8	18.0	.85	62.2	12.6	114.6	20.8				.83	74.1	14.4	126.2	21.9
May	.82	43.0	9.5	74.4	14.9	.83	53.4	11.0	94.5	17.6				.82	62.8	12.3	107.0	19.0
July	.77	37.5	8.4	57.6	11.9	.78	46.6	9.5	104.3	14.1				.76	56.1	10.6	83.2	15.4
Sep.	.83	41.8	9.0	74.7	14.2	.83	53.0	10.4	94.2	16.8				.79	66.5	11.8	105.5	18.1
Nov.	.88	47.9	9.9	100.0	18.2	.88	60.1	11.9	125.3	21.4				.85	75.0	13.9	141.2	23.1
500 mb																		
Jan.	.76	46.6	8.5	65.9	12.5	.80	51.8	9.6	79.3	13.9				.76	62.8	10.6	87.2	14.3
Mar.	.82	38.4	7.8	64.3	12.6	.84	46.3	8.9	80.5	14.4	.76	52.7	9.2	.81	55.5	10.1	88.7	15.2
May	.81	30.8	6.5	51.2	9.8	.82	38.1	7.4	65.9	11.6	.62	77.7	20.5	.82	44.5	8.3	75.0	12.6
July	.74	26.5	5.6	38.4	7.5	.77	32.6	6.2	49.7	9.0	.67	36.6	6.4	.76	38.1	6.9	56.4	9.9
Sep.	.82	29.6	6.1	50.3	9.3	.83	36.6	6.9	63.7	11.0	.75	42.4	7.2	.79	46.0	7.8	72.3	12.1
Nov.	.86	35.4	7.0	69.8	12.3	.87	43.0	8.2	88.1	14.6				.85	53.0	9.5	100.6	15.8
850 mb																		
Jan.	.74	37.2	7.3	47.0	8.2	.79	39.3	7.9	56.1	9.0				.74	48.5	8.6	62.2	11.1
Mar.	.79	30.8	6.4	43.9	8.0	.81	35.4	7.3	54.3	9.2				.78	42.4	8.1	60.4	11.4
May	.77	24.1	5.4	34.5	6.1	.79	28.4	5.8	43.9	7.3				.79	33.2	6.5	50.0	9.3
July	.65	23.8	5.1	26.5	4.9	.71	26.8	5.4	34.5	6.0				.71	30.5	6.8	38.7	7.3
Sep.	.76	25.0	5.4	35.1	6.3	.79	29.6	5.9	44.8	7.6				.76	36.0	6.5	50.6	9.6
Nov.	.84	28.0	5.9	48.8	8.0	.85	33.2	6.7	61.3	9.4				.82	40.9	7.6	68.6	11.6
1000 mb																		
Jan.	.77	39.0	8.5	54.0	9.9	.80	43.6	9.4	64.0	10.9				.76	52.7	10.3	70.4	11.1
Mar.	.81	32.6	7.6	50.3	9.7	.83	38.1	8.7	61.9	11.0				.79	45.7	9.6	67.7	11.4
May	.75	27.1	6.4	38.7	7.4	.77	33.2	7.0	49.1	8.7				.76	37.5	7.8	54.6	9.3
July	.63	25.9	5.9	29.0	5.8	.69	29.6	6.3	36.9	6.9				.68	33.5	6.8	40.9	7.3
Sep.	.76	28.0	6.5	39.6	7.7	.77	34.1	7.1	50.3	9.1				.75	39.9	7.9	55.5	9.6
Nov.	.85	30.2	6.8	54.9	9.5	.85	37.5	7.9	68.3	11.1				.82	45.1	8.9	75.3	11.6

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.	.84	47.3	10.8	89.9	17.3	.80	65.5	13.6	108.5	19.5				.70	86.0	16.4	114.9	19.6
Mar.	.89	40.2	10.1	83.8	17.2	.87	56.7	12.8	104.3	19.8				.83	70.7	14.8	111.6	20.4
May	.84	36.3	9.1	64.9	13.8	.86	43.6	10.6	82.3	16.7				.83	54.5	11.9	95.4	18.2
July	.83	34.8	8.2	60.4	12.0	.86	40.5	8.9	79.6	14.8				.85	49.7	10.8	92.7	16.6
Sep.	.85	33.9	8.2	65.5	13.2	.85	45.4	9.8	88.1	16.7				.84	57.6	11.5	100.6	18.4
Nov.	.89	45.7	10.0	106.4	19.3	.87	62.8	12.7	137.5	23.0				.82	83.8	15.8	155.2	24.6
300 mb																		
Jan.	.86	54.3	11.6	110.4	22.0	.82	71.0	14.6	128.4	24.0				.74	90.9	17.3	131.7	23.6
Mar.	.91	44.5	10.9	110.7	23.0	.89	62.5	13.9	133.5	26.2				.84	79.3	16.3	139.9	26.3
May	.88	35.7	9.1	78.4	16.9	.88	44.8	10.8	98.5	20.3				.86	56.4	12.4	111.3	21.8
July	.85	31.7	7.5	61.0	12.1	.86	38.7	8.6	79.6	14.8				.85	46.6	9.8	91.5	16.5
Sep.	.88	34.1	8.4	75.0	15.3	.88	44.8	10.1	98.5	19.1				.86	56.7	11.8	111.3	20.7
Nov.	.90	49.7	11.0	120.7	23.4	.87	67.1	14.1	151.8	27.0				.83	88.4	17.3	169.8	28.4
500 mb																		
Jan.	.83	43.3	8.7	81.4	16.3	.81	54.3	10.5	94.5	17.7				.77	64.9	12.1	97.9	17.5
Mar.	.90	34.1	7.7	79.6	16.0	.88	47.3	9.7	97.3	18.4	.85	50.9	9.9	.84	57.9	11.3	102.7	18.6
May	.86	25.0	6.0	51.5	10.6	.86	32.3	7.2	66.2	12.8	.73	65.2	18.2	.84	39.6	8.5	74.4	13.8
July	.81	22.6	4.9	38.7	7.5	.85	25.6	5.4	50.6	9.1	.78	31.4	5.8	.84	30.5	6.3	57.9	10.1
Sep.	.87	22.9	5.3	47.6	9.5	.89	28.4	6.3	63.4	12.0	.83	35.1	6.9	.87	35.7	7.4	71.6	13.0
Nov.	.88	36.3	7.7	81.7	15.5	.87	48.2	9.8	104.0	18.2				.83	61.3	11.7	117.1	19.2
850 mb																		
Jan.	.83	30.8	6.5	53.5	10.1	.81	36.3	7.6	61.6	10.9				.75	43.6	8.7	63.1	10.6
Mar.	.88	26.2	5.8	51.2	9.9	.85	35.4	7.4	63.1	11.6				.82	41.8	8.4	66.8	11.5
May	.76	22.6	4.9	32.3	6.1	.78	26.5	5.5	41.5	7.6				.76	30.8	6.3	45.7	7.9
July	.69	21.6	4.5	25.9	4.9	.74	24.1	4.9	33.5	6.1				.78	27.1	5.5	36.3	6.3
Sep.	.81	20.1	4.5	31.7	6.2	.84	22.9	5.2	41.2	7.7				.83	29.0	6.1	45.4	8.1
Nov.	.86	26.8	5.6	52.1	9.3	.84	35.1	7.1	64.0	10.8				.81	38.5	8.1	68.6	11.0
1000 mb																		
Jan.	.85	33.8	7.9	63.7	12.3	.82	41.2	9.5	73.5	13.4				.77	48.5	10.5	73.2	12.8
Mar.	.81	32.6	7.6	50.3	9.7	.83	38.1	8.7	61.9	11.0				.79	45.7	9.6	67.4	11.4
May	.72	27.1	6.3	36.9	7.6	.76	30.8	6.9	47.3	9.4				.71	37.8	8.1	51.2	9.7
July	.66	24.4	5.3	29.6	6.1	.71	27.4	6.0	36.9	7.3				.71	30.5	6.4	39.3	7.4
Sep.	.82	23.8	5.7	39.9	8.1	.85	27.1	6.4	51.2	9.9				.81	33.8	7.5	55.8	10.5
Nov.	.86	30.5	6.8	59.8	11.1	.84	39.6	8.5	72.6	12.8				.81	47.6	9.8	76.2	12.8

C. Europe--Area 3 (143 Grid Points)

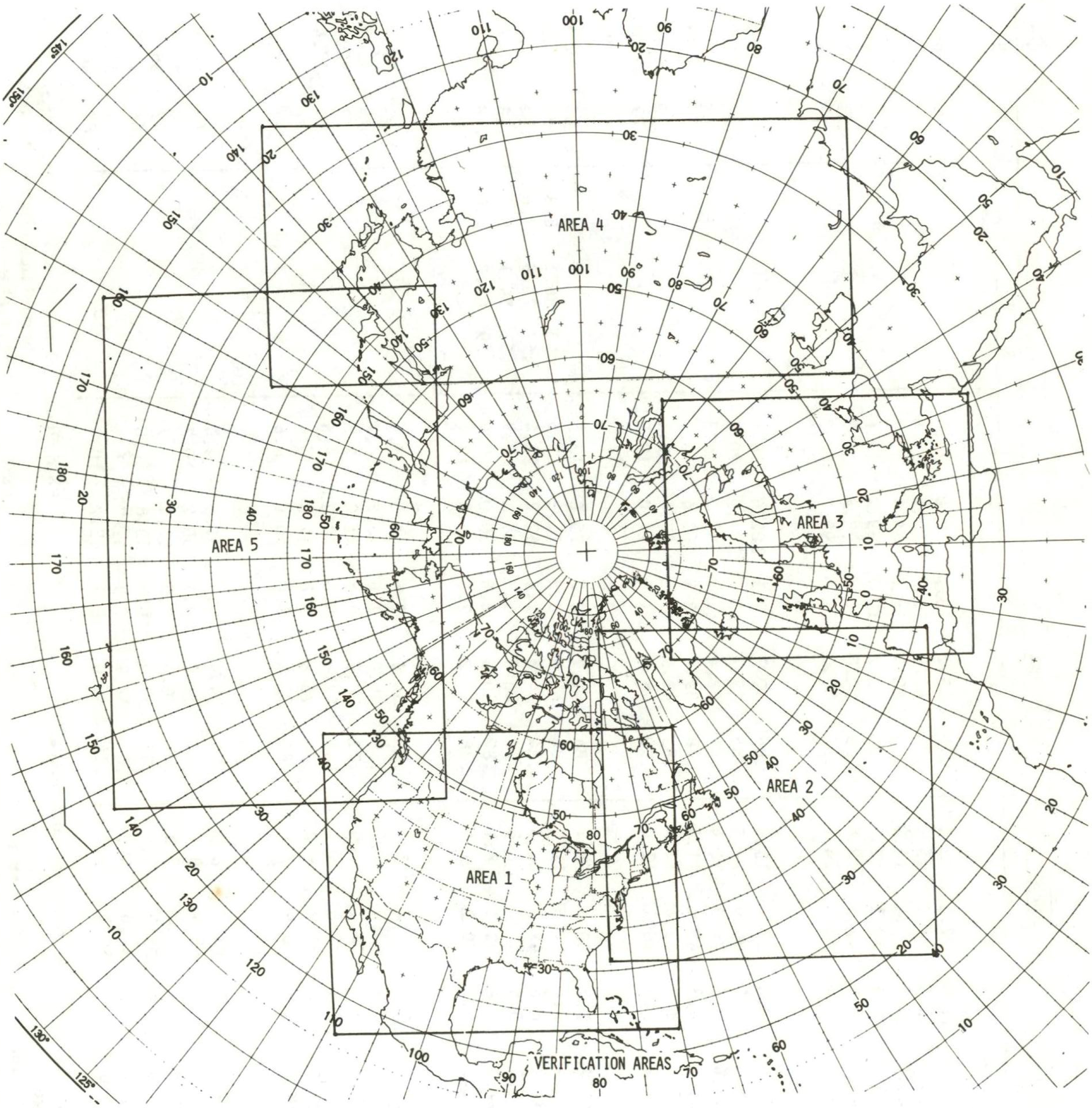
	26 hours					36 hours								48 hours				
	PE MODEL			PERS		PE MODEL			PERS		BAROTROPIC			PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	R	H	W	R	H	W	H	W
200 mb																		
Jan.	.83	53.5	9.4	100.0	16.3	.80	66.2	11.1	117.1	18.2				.75	84.5	13.5	124.1	18.7
Mar.	.85	46.6	8.2	85.5	14.0	.86	56.7	10.1	114.3	17.4				.83	69.8	11.4	127.7	18.8
May	.80	39.0	7.9	68.6	11.8	.81	50.3	9.7	89.3	14.5				.82	58.5	10.5	103.4	15.7
July	.77	39.3	8.2	61.9	12.3	.79	48.2	9.7	78.7	14.9				.78	57.0	10.8	88.7	16.2
Sep.	.87	47.9	9.4	95.1	15.9	.85	63.1	14.3	118.6	18.9				.79	80.2	13.7	129.9	19.8
Nov.	.89	47.3	9.0	106.7	16.9	.89	61.3	10.9	139.0	20.8				.86	78.4	13.0	54.0	22.4
300 mb																		
Jan.	.87	56.1	10.1	117.4	20.2	.82	74.1	12.7	134.8	22.1				.78	91.8	15.1	141.8	22.5
Mar.	.89	49.1	9.0	107.3	18.3	.89	62.2	11.4	138.1	22.0				.85	79.0	13.7	154.6	24.0
May	.86	41.8	8.2	88.7	15.2	.86	53.7	10.2	113.1	18.5				.86	64.3	11.6	131.7	20.3
July	.84	37.8	7.8	72.3	14.0	.83	49.4	9.6	93.9	17.3				.82	57.9	11.0	104.9	18.9
Sep.	.88	51.5	10.2	110.1	18.7	.86	69.2	12.4	134.6	21.8				.81	85.4	14.5	145.3	22.7
Nov.	.91	52.1	9.7	126.5	20.8	.90	68.3	12.1	161.0	25.2				.86	89.0	14.7	179.3	27.1
500 mb																		
Jan.	.85	41.8	7.4	82.0	20.8	.83	54.0	9.2	97.3	15.7				.80	65.9	10.6	105.5	16.4
Mar.	.87	36.9	6.5	75.6	12.2	.88	45.7	8.1	97.9	15.6	.82	57.3	9.4	.85	57.3	9.7	110.7	17.1
May	.85	31.7	5.9	63.7	10.6	.85	40.5	7.3	82.6	13.0	.69	91.8	15.4	.85	47.6	8.1	95.4	14.3
July	.81	26.8	5.1	47.6	8.8	.82	34.5	6.2	62.8	11.1	.77	38.4	6.6	.83	39.0	6.9	71.0	12.2
Sep.	.87	36.0	6.6	74.7	12.2	.86	47.9	8.0	93.9	14.4	.80	57.0	8.8	.81	58.5	9.5	102.0	15.3
Nov.	.90	38.1	6.8	86.3	13.8	.89	49.1	8.4	112.2	17.0				.86	62.5	10.1	125.0	18.4
850 mb																		
Jan.	.81	32.9	5.7	58.5	8.9	.80	41.5	6.8	70.1	9.9				.77	50.3	7.7	79.6	10.8
Mar.	.81	26.8	4.5	46.3	7.5	.82	32.6	5.6	58.8	9.1				.80	40.2	6.4	67.7	10.0
May	.78	23.2	4.2	37.2	6.0	.79	29.3	5.0	47.9	7.2				.79	33.8	5.6	54.0	7.9
July	.73	19.8	3.8	28.7	5.0	.77	23.5	4.3	37.5	6.2				.78	26.5	4.7	42.1	6.7
Sep.	.85	25.0	4.5	49.4	7.4	.85	32.3	5.5	61.6	8.7				.81	39.0	6.4	69.5	9.5
Nov.	.85	28.4	4.7	54.9	7.9	.84	36.6	5.8	72.3	9.6				.81	44.8	7.0	81.1	10.4
1000 mb																		
Jan.	.83	34.8	6.3	65.2	10.2	.81	45.1	7.5	76.5	11.0				.76	58.2	8.9	87.2	12.1
Mar.	.83	27.7	5.2	50.3	8.5	.82	36.0	6.4	62.5	9.9				.78	45.1	7.5	71.0	10.9
May	.77	25.3	4.7	39.6	6.6	.77	32.0	5.7	48.5	7.7				.75	37.8	6.5	54.3	8.5
July	.71	22.0	4.4	30.8	5.4	.75	25.6	4.8	38.1	6.4				.74	29.9	5.4	72.7	7.0
Sep.	.85	27.4	5.1	53.7	8.4	.84	34.1	6.0	63.4	9.3				.80	42.1	7.2	71.6	10.2
Nov.	.87	29.9	5.2	61.9	8.9	.85	39.3	6.3	78.7	10.4				.81	50.3	7.8	88.1	11.4

D. Asia--Area 4 (275 Grid Points)

	24 hours					36 hours								48 hours				
	PE MODEL			PERS		PE MODEL			PERS		BAROTROPIC			PE MODEL			PERS	
	R	H	W	H	W	R	H	W	H	W	R	H	W	R	H	W	H	W
200 mb																		
Jan.	.71	64.3	12.8	72.3	13.6	.79	65.2	13.5	93.0	16.4				.74	79.9	14.8	100.3	16.6
Mar.	.82	50.9	11.1	77.7	15.0	.83	61.0	13.2	98.2	17.8				.82	70.4	14.9	111.9	19.3
May	.78	46.0	10.5	67.4	14.9	.76	60.4	12.0	85.7	17.7				.77	66.5	13.5	92.1	18.5
July	.69	43.3	9.9	56.1	12.6	.73	49.7	10.7	69.2	14.6				.72	58.2	12.1	77.1	15.8
Sep.	.75	43.3	9.6	62.2	12.8	.79	50.0	10.8	78.4	15.1				.75	62.5	12.4	88.1	16.4
Nov.	.83	44.5	10.2	76.8	14.7	.86	50.6	11.6	98.2	17.3				.83	65.5	13.1	110.7	18.9
300 mb																		
Jan.	.81	51.8	10.5	82.0	15.8	.84	50.7	12.1	102.4	18.4				.82	67.7	12.9	112.2	19.0
Mar.	.85	46.3	10.2	86.9	17.3	.85	59.1	12.1	107.9	20.2				.85	67.7	13.7	121.3	21.8
May	.82	43.6	9.6	74.7	16.4	.84	52.4	11.0	93.6	19.3				.82	61.0	12.5	103.4	20.6
July	.71	35.7	8.3	49.1	11.3	.78	39.0	8.9	60.4	13.1				.75	46.6	10.1	68.3	14.4
Sep.	.79	38.1	8.6	61.6	12.7	.83	43.9	9.5	77.4	15.1				.79	54.0	10.8	86.3	16.3
Nov.	.88	41.2	9.5	88.1	17.0	.90	48.5	11.1	111.0	19.9				.87	41.3	12.6	125.3	21.8
500 mb																		
Jan.	.80	40.2	7.7	60.4	11.7	.84	41.2	8.7	75.0	13.5				.83	46.3	9.0	83.2	29.0
Mar.	.81	35.4	7.4	57.6	11.6	.84	41.8	8.2	71.3	13.5	.63	56.1	8.8	.83	47.0	9.3	78.9	14.2
May	.80	31.1	6.6	49.1	10.5	.84	34.8	7.4	62.2	12.4	.57	76.8	17.6	.82	39.6	16.8	69.5	13.4
July	.66	25.3	5.5	30.2	6.8	.74	26.8	5.9	38.1	7.9	.51	34.1	6.2	.73	30.8	6.6	43.3	88.7
Sep.	.76	27.1	5.9	39.6	8.1	.80	30.5	6.5	50.0	9.6	.59	41.8	7.0	.78	36.6	7.1	55.8	10.3
Nov.	.86	31.1	6.5	60.7	11.4	.88	34.8	7.5	76.8	13.4				.86	42.1	8.4	86.9	14.6
850 mb																		
Jan.	.67	35.6	7.5	37.2	7.1	.75	34.1	7.6	44.5	7.9				.74	37.5	7.9	48.4	8.1
Mar.	.75	31.4	6.9	40.2	7.7	.79	36.6	7.6	48.2	8.7				.76	41.8	8.3	53.0	9.1
May	.74	26.8	5.8	34.1	7.0	.78	28.7	6.3	41.8	7.8				.77	32.0	7.0	46.6	8.6
July	.57	24.1	5.3	22.6	4.7	.61	27.4	5.6	29.3	5.6				.67	27.4	5.9	32.6	6.2
Sep.	.69	23.8	5.5	27.7	5.8	.73	26.8	5.8	34.8	6.8				.74	29.6	6.3	38.7	7.3
Nov.	.78	29.6	6.5	40.9	7.3	.83	31.4	7.0	50.6	8.6				.81	35.7	7.8	55.5	9.1
1000 mb																		
Jan.	.69	38.1	9.3	43.3	8.6	.74	39.9	9.8	51.5	9.4				.73	45.1	10.5	55.5	9.6
Mar.	.79	33.2	8.2	48.9	9.4	.81	38.7	9.3	58.2	10.7				.79	45.1	10.2	62.8	11.0
May	.75	29.6	6.9	41.2	8.5	.75	36.0	7.9	51.2	9.7				.77	36.9	8.4	54.3	10.2
July	.58	25.6	6.2	25.9	5.6	.58	32.0	6.9	33.8	6.8				.66	31.4	7.3	37.2	7.3
Sep.	.68	27.1	7.3	32.0	6.9	.69	32.9	7.9	41.2	8.4				.71	35.4	88.6	44.2	8.6
Nov.	.84	29.0	7.1	50.0	9.1	.84	36.0	8.4	62.2	10.8				.83	40.5	9.2	68.0	11.3

R Correlation coefficient of forecast and actual height change
H Standard Deviation of Error in meters
W Root-mean-square vector geostrophic wind error in meters per second

PE MODEL Operational 6-layer primitive equation baroclinic forecast model
PERS Persistence forecast
BAROTROPIC Operational barotropic model


AREA 1
AREA 2
AREA 3
AREA 4
AREA 5
VERIFICATION AREAS

Precipitation Threat Scores* for the Limited-Area Fine-Mesh Model for 1975

Threat scores are computed at 0000 and 1200 GMT for a 60-station network covering the 48 states and averaged for each month. These values are for the occurrence of precipitation within the 12-hr period before the end of the forecast period. For example, under the column "36-hr Forecasts" the threat scores are based on the forecast and occurrence of precipitation between the 24th and 36th hour.

THREAT SCORES

Month	24-hr Forecast	36-hr Forecast
Jan.	42.36	
Feb.	45.24	
Mar.	47.39	
Apr.	43.28	
May	35.04	
June	34.50	
July	29.57	24.77
Aug.	29.12	26.42
Sep.	38.10	33.54
Oct.	45.58	38.46
Nov.	43.17	37.03
Dec.	41.35	32.71
Annual	43.8	31.8 (6-months)

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* Threat Score = $\frac{H}{F + O - H} \times 100$

where H = Number of correct forecasts
F = Number of precipitation forecasts
O = Number of precipitation occurrences.

PART VII PUBLICATIONS

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Carter, G.M., *Automated Prediction of Surface Wind from Numerical Model Output*, Mon. Wea. Rev., Vol. 103, October 1975, pp. 866-873.

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NMC OFFICE NOTES

106 - *Note on Insertion Procedures for Meteorological Data Assimilation*
Ronald D. McPherson and Robert E. Kistler

107 - *A Comparison of Radiosonde Reports Received by Four Major U.S. Global Data Processing Centers*
Arthur R. Thomas

108 - *NMC Archives* Robert Gelhard

109 - *The NMC Operational Global Energy Program*
Alvin J. Miller, William Collins, and Dean Dubofsky

110 - *Progress, Problems, and Prospects in Meteorological Data Assimilation* Ronald D. McPherson

111 - *Theory of Smoothing Discrete Functions*
Frederick G. Shuman and Frederick G. D. Shuman (U. of Md.)

112 - (not released)

113 - (not released)

114 - *Comparisons between NESS and Wisconsin Cloud-Tracked Winds*
Paul Lemar and William Bonner

115 - *The NMC Front End to the NOAA 360/195 System* H. A. Bedient

116 - *Multivariate Objective Analysis of Temperature and Wind Fields*
K. H. Bergman

117 - *Airway Surface Observations (SA's) Stored on the 360/195 System (Hourly Surface Reports)*
William K. Byle and James E. McDonell

118 - (not released)

119 - *Analysis Error as a Function of Observation Density for Satellite Temperature Soundings with Spatially Correlated Errors* Kenneth H. Bergman and William D. Bonner

120 - *The Economics of Truncation Error Control Versus High Resolution*
Frederick G. Shuman

TDL OFFICE NOTES

75-1 - *Comparative Verification of Local and Guidance Surface Wind Forecasts No. 2*
G.M. Carter, H.R. Glahn and G.W. Hollenbaugh

75-2 - *Computer Programs for the MOS Development System IBM 360/195 Version*
H.R. Glahn, G.W. Hollenbaugh and F.T. Globokar

75-3 - *Testing the LFM for PoP Forecasting*
H.R. Glahn and J.R. Bocchieri

75-4 - *Automated Prediction of Thunderstorms, Drizzle, Rain, and Showers--No. 2.* G.M. Carter

75-5 - *Forecasting Surface Wind Direction Using Deviations from the PE Boundary Wind* G.M. Carter

75-6 - *Evaluation of Computer-Produced Lake Erie Storm Surge Forecasts from September 1, 1974 through April 30, 1975.*
W.S. Richardson

75-7 - *Comparative Verification of Local and Guidance Cloud Amount Forecasts--No. 1* G.M. Carter

75-8 - *Simple Properties of Chapeau Functions and Their Application to the Solution of the Advective Equation*
P.E. Long, Jr. and F.J. Hicks

75-9 - *Comparative Verification of Local and Guidance Surface Wind Forecasts--No. 3* G.M. Carter and G.W. Hollenbaugh

75-10 - *Current Status of Probability of Precipitation Amount (POPA) Forecasting* R.J. Bermowitz and E.A. Zurndorfer

TECHNICAL MEMORANDA

ERL ARL-49 *Two Case Studies Correlating the Baseline CO_2 Record at Mauna Loa with Meteorological and Oceanic Parameters*
A.J. Miller, J.M. Miller and R.M. Rotty

NWS NMC-56 *Theoretical and Experimental Comparison of Selected Time Integration Methods Applied to Four-Dimensional Data Assimilation* **R.D. McPherson and R.E. Kistler**

NWS TDL-54 *Climatology of Lake Erie Storm Surges at Buffalo and Toledo* **N.A. Pore, H.P. Perrotti and S.W. Richardson**

NWS TDL-55 *Some Physical and Numerical Aspects of Boundary Layer Modeling at the Techniques Development Laboratory*
P.E. Long and W.A. Shaffer

NWS TDL-56 *Dissipation, Dispersion, and Difference Schemes*
P.E. Long

NWS TDL-57 *A Predictive Boundary Layer Model*
W.A. Shaffer and P.E. Long

NWS TDL-58 *A Preliminary View of Storm Surges Before and After Storm Modifications for Alongshore Moving Storms*
C.P. Jelesnianski and C.S. Barrientos

ABBREVIATIONS AND ACRONYMS

AFOS	Automation of Field Operations and Services
AMS	American Meteorological Society
BLM	Boundary Layer Model
CFL	Courant-Frederichs-Lewy
CPU	Central Processing Unit
DST	Data Systems Test
FGGE	First Garp Global Experiment
GARP	Global Atmospheric Research Program
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute for Space Studies
HIRS	High-resolution Infrared Sounder
IBM	International Business Machines
ITPR	Infrared Temperature Profile Radiometer
KCRT	Keyboard Cathode Ray Tube
LFM	Limited-area Fine-mesh Model
LRIR	Limb Radiance Infrared Radiometer
MDR	Manually Digitized Radar
MOS	Model Output Statistics
MSL	Meteorological Satellite Laboratory
MWR	Monthly Weather Review
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NESS	National Environmental Satellite Service
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
NWS	National Weather Service
NSSFC	National Severe Storms Forecast Center
PE	Primitive Equation
PoF	Probability of Frozen Precipitation
PMR	Pressure Modulated Radiometer

QPF	Quantitative Precipitation Forecasts
RADAT	Radiosonde Early Transmission
REEP	Regression Estimation of Event Probability
RMS	Root-mean-square
SPLASH	Special Programs to List Amplitudes of Surges of Hurricanes
SST	Supersonic Transport
STRATWARM	Stratospheric Warmings
TAP	Terminal Alerting Procedure
TWERLE	Tropical Wind, Energy Conversion and Reference Level Experiment
UCLA	University of California at Los Angeles
VIL	Vertically Integrated Liquid Water Content
VFM	Very Fine Mesh Model
VTPR	Vertical Temperature Profile Radiometer
3L GLOBAL	Three-layer Global Model
8L GLOBAL	Eight-layer Global Model
8L HEM	Eight-layer Hemispheric Model
6L PE	Six-layer Primitive-Equation Model