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EXPERIMENTS IN OBJECTIVE UPPER-WIND ANALYSIS AND FORECASTING

July 1964

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Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

FINAL REPORT

EXPERIMENTS IN OBJECTIVE UPPER-WIND ANALYSIS AND FORECASTING

by Elmar R. Reiter and
Patricia E. White

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Project Leader: Elmar R. Reiter

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TABLE OF CONTENTS

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ABSTRACT

This report describes the progress of work accomplished during the second phase of the project, 1 August 1962 through 22 November 1963.

The introduction (Chapter I) outlines the purpose and scope of the study, and also reviews some of the earlier work done during the first phase of the project. The objectives of the research program are classified into (1) data handling, (2) objective analysis, and (3) objective forecasting of parameters characterizing the layer of maximum wind (LMW).

Chapter II describes the data handling aspects. Error checking and harmonic analysis of vertical wind profiles are discussed. Computer programs in FORTRAN for an IBM 7090 are included in an appendix.

In Chapter III, a method of objective horizontal analysis of LMW parameters is discussed, which is based on the concept of fitting a quadratic function to station observations in order to arrive at grid point data. Machine programs, again, are listed in an appendix.

Chapter IV gives a detailed outline of various approaches to 12 - and 24 - hour kinematic extrapolation forecasts. Skill evaluations are presented in comparison to persistence. Various smoothing techniques on input and output have been tested as to their effect in reducing forecasting errors. Forecasting examples are given in the form of tables and graphs. A 25-day period (January 1 through 25, 1961) has been selected to test the more promising techniques of extrapolating LMW parameters. All forecasting programs, again, are listed in appendices.

Chapter V recommends further tests, especially to improve the quality of objective analysis. The extraction of wind data at explicit flight levels also will have to be left to future programming efforts.

LIST OF FIGURES

LIST OF TABLES

Experiments in Objective Upper-Wind Analysis and Forecasting

by

Elmar R. Reiter and Patricia E. White

I. Introduction:

The purpose of this study, as outlined by Reiter (1962a) was to develop high-speed techniques of objective upper-level wind analysis and forecasting, which could be utilized by an Automatic Air Traffic Control (ATC) System. The research conducted under this objective may be categorized into three phases:

(1) Data handling

(2) Objective analysis

(3) Objective forecasting

As has been pointed out in the report quoted above, it was anticipated that wind forecasts would have to be issued for any point over the continental United States contained in a layer between 20,000 and 50,000 ft.

To meet this forecasting problem, three different approaches are available. One of them had to be ruled out a priori because of its impracticability.

(1) Correctly, a baroclinic model of the atmosphere should be considered in arriving at numerical wind forecasts. The quality of wind forecasts for fast-flying aircraft will critically depend upon the accurate prediction of vertical and horizontal shears in the jet-stream region. The presently available baroclinic models were not yet considered adequate in handling these detailed shear forecasts to a sufficient degree of accuracy (Wiin-Nielsen 1962).

(2) Objective analyses conducted on isobaric levels have been produced successfully by the JNWP group of the U.S. Weather Bureau. These analyses could easily be adapted for kinematic extrapolation forecasts. To arrive at a wind forecast for an arbitrary point within the air space 20,000 to 50,000 ft. could simply be a matter of interpolation between wind values at adjacent isobaric levels and neighboring grid points.

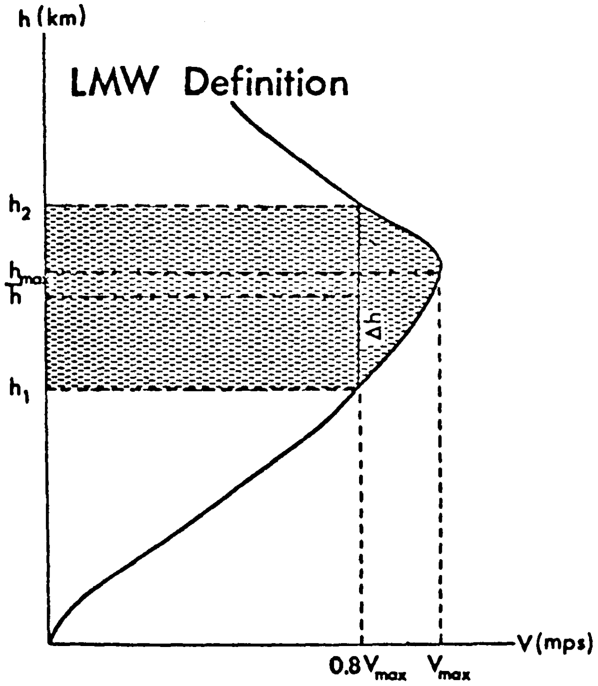
A difficulty arises from the fact that the analyses and forecasts performed at various isobaric levels will have to be made vertically consistent. In view, again, of the strong vertical and horizontal shears present in the jet stream region this appeared to be a difficult task.

(3) Vertical consistency of the wind data may be achieved by utilizing the layer of maximum wind (LMW) concept as outlined in Fig. 1 (Reiter 1957, 1958). Mean wind speed and direction of the layer, thickness and height of the layer, constitute vertically integrated parameters which now may be used for horizontal analysis and forecasting.

The task still remains to recover wind values for individual flight levels. This, however, does not present more of a problem than the equivalent procedure mentioned under (2).

The analysis and forecasting experiments described below followed this approach.

Fig. 1: Definition of LMW parameters: V_{max} = maximum wind speed; 0.8 V_{max} = 80 percent of maximum wind speed; h_{max} = height of wind maximum; $\bar{h}$ = $(h_1 + h_2)/2$ = mean height of LMW



II. Data handling

As has been described in the previous report (Reiter 1962a) the original minute-by-minute wind observations of all rawinsonde stations of the continental United States were used. The data have been made available on punched cards by the National Weather Records Center, Asheville, N.C. Wind measurements of the following months have been received and processed: January, February, June, and July, 1961. August 1961 and December 1960 have been received, but not yet processed.

The layout in which the data appeared may be taken from Appendix 1.

Processing of the raw data consisted of (a) an error checking program, (b) harmonic analysis of the vertical wind profiles, and (c) the extraction of the characteristic parameters of the LMW. This program was checked out on the IBM 7090 of the National Bureau of Standards, Boulder. The major processing runs of the data were subsequently performed on the IBM 7090 of NAFEC, Atlantic City.

Appendix 2 contains the flow diagrams, symbol definitions and FORTRAN programs of the error checking, harmonic analysis and LMW routines.

Figs. 2 and 3 show unsmoothed and harmonically smoothed wind profiles for a "baroclinic" and a "barotropic" case. It is realized, that some of the fluctuations of wind speed which are cut off by the smoothing routine may be quite real and of local importance. Since they represent, at best, mesostructural details which would be representative only for a relatively small region, they may be neglected in large-scale analysis, even though some of these details may persist for several hours (Reiter, 1962b, 1963a, Reiter, Lang et al., 1961; Riehl, 1961).

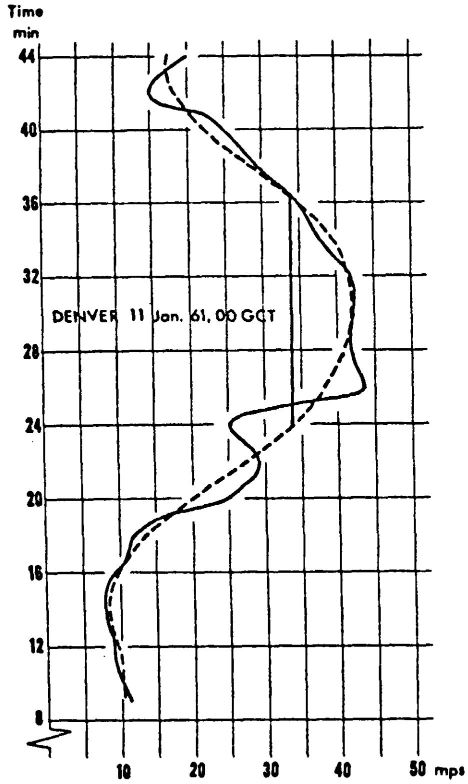


Fig. 2: "Baroclinic" sounding, Denver, Colorado, 11 January, 00 GCT. Solid line: original wind measurements. Dashed line: wind profile after harmonic analysis. Heavy vertical line indicates extent of LMW.

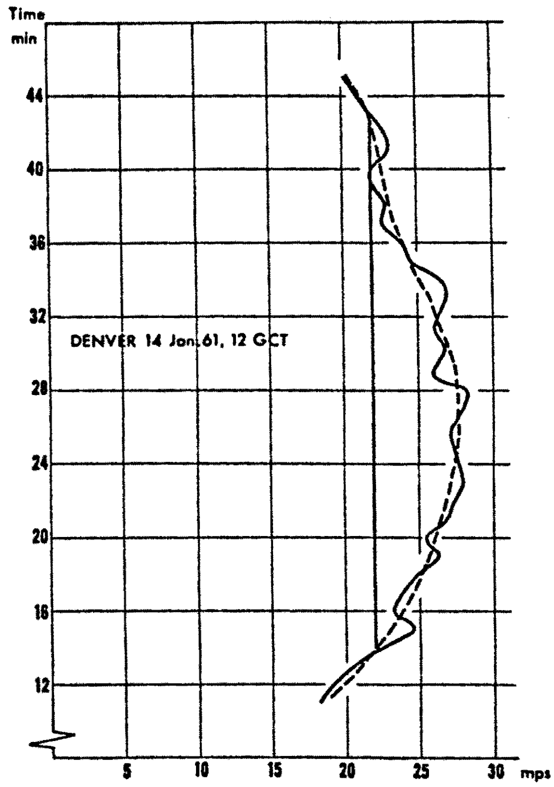


Fig. 3: "Barotropic" sounding, Denver, Colorado, 14 January 1961, 12 GCT. Solid line: original wind measurements Dashed lines: wind profile after harmonic analysis. Heavy vertical line indicates extent of LMW.

A certain "noise" in the LMW parameters will have to be expected depending on how the harmonic analysis will cut off the various fluctuations in the vertical profiles. Therefore, the horizontal analysis of these parameters will also require a certain amount of smoothing.

As a whole, the data-handling part of the program has performed very satisfactorily. The error checking routine seems to eliminate the common mis-punches and inconsistencies in the input data. An example of the final printout of this phase of the program is presented in Appendix 3.

III. Objective Horizontal Analysis of LMW Parameters

Baer (1963) has described a method of fitting a quadratic surface to LMW parameters measured over individual stations and so arriving at the appropriate values in the gridpoints of a rectangular grid.

For the analysis and forecasting schemes described in the following a quadratic grid of 3 cm grid distance on a polar stereographic projection of scale 1: 10,000,000 at latitude 60° N has been used. The grid was centered at longitude 100° W with one grid point lying at 30° N. (Fig.4).

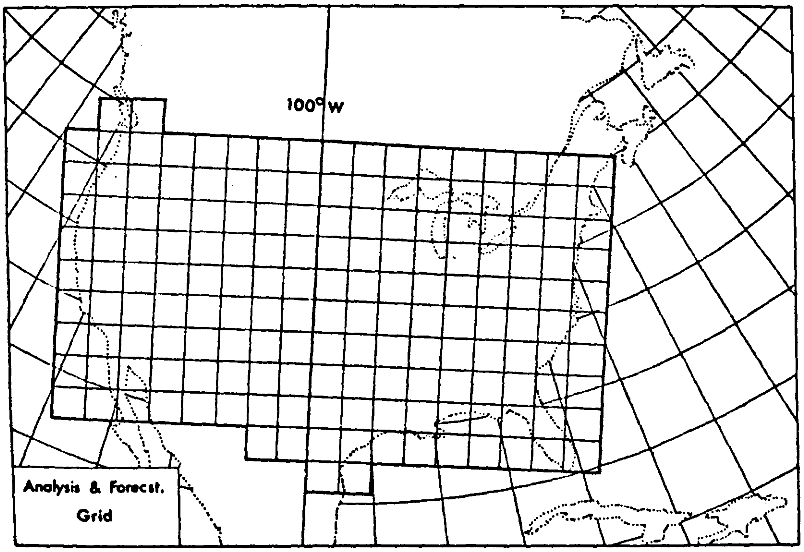


Fig. 4: Basic grid used for objective analysis and forecasting of LMW parameters.

Since the quality of upper wind forecasts will be most sensitive to the accurracy with which the jet axis is predicted, the greatest efforts were devoted to forecasts of the fields of mean wind speed and wind direction of the LMW.

As mentioned earlier, due to some "noise" in the LMW data, which remained even after harmonically analysing the vertical wind profiles, a certain amount of smoothing in the horizontal analyses was required.

This was accomplished by fitting again a quadratic (or plane) surface to station and gridpoint data available from a preliminary and unsmoothed numerical analysis.

The flow diagram, symbol list and FORTRAN program for these computations are presented in Appendix 4.

Most of the gridpoints over the continental United States which might be missing after the first interpolation procedure due to poor station coverage will be filled in during this second interpolation run.

While this second "smoothing run" performed adequately for mean wind speed and direction of the LMW, its height and thickness had to be analyzed in a different fashion: As mentioned in an earlier report (Reiter 1962a), barotropic soundings were assigned arbitrary values of $\bar{h}$ = 20 km and $\wedge h$ = 7 km. If the same smoothing technique as used with wind speeds and directions were used, the "barotropic" regions would be flattened out considerably and, by the same token, zones with strong shears and with low values of $\bar{h}$ would be eliminated almost entirely. In order to prevent this, yet still be able to fill in grid points missing after the first run of the program, original station data were weighed with a factor of three during the second run, over grid point values computed during the first run.

Results of the objective analysis procedure outlined above were very encouraging. Figs. 5, 6 and 7 show typical examples of analysis, containing gridpoint as well as station data. With the smoothing technique described above, the data coverage over the continental United States as well as the agreement between gridpoint and station data is very satisfactory, especially in wind speeds and wind directions. Thicknesses and heights of the LMW show strong gradients in the vicinity of the jet stream. Any kind of objective analysis will have a tendency to smooth out these gradients.

Barotropic soundings defined as $\bar{h} > 20$ km, $\wedge h > 7$ km, have been marked as such in the thickness and height analyses. Mean wind speeds and directions have been computed and entered into the analyses even for these barotropic soundings in order to warrant continuity of analysis. It is assumed that under barotropic conditions the vertical wind shears near the level of maximum wind are small enough to be neglected for practical flight-planning purposes.

Because of the unavoidable smoothing introduced by the two objective analysis runs, mean height values $\bar{h} > 18$ km and mean thickness values $\wedge h > 6$ km should be considered as indicating barotropic conditions for all practical purposes (see Figs. 5, 6 and 7). These values approach the ones originally suggested by Reiter. (1958) to characterize barotropic conditions ($\bar{h}_{barotropic}$ = 15 km in extra-tropical latitudes; $\wedge h_{barotropic}$ = 5 km; see also Reiter, 1963b). The reason why these more stringent values have not been used from the start lies in the fact that the larger number of "barotropic" stations which would thus have resulted, would have made an objective analysis more difficult and less coherent. This has been brought out clearly by preliminary tests conducted during the early stages of this project.

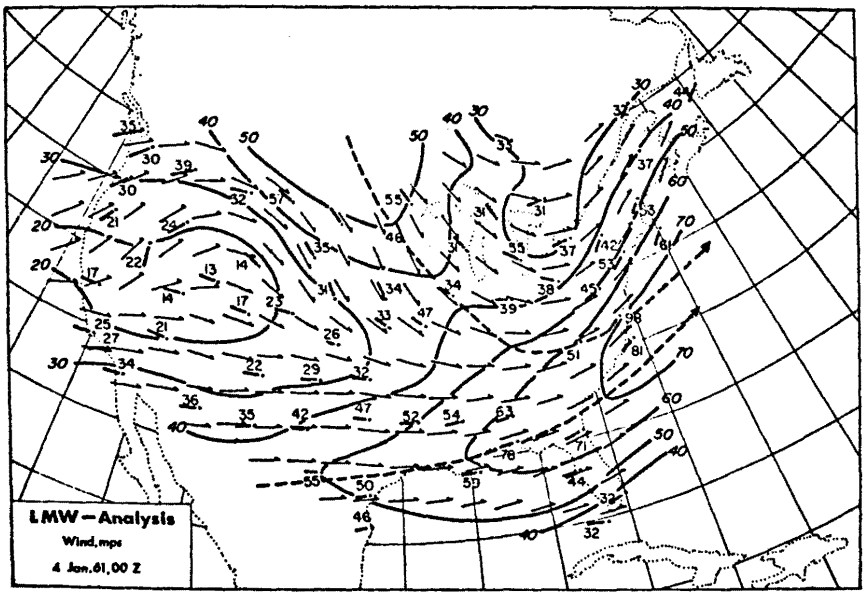


Fig. 5: Objective analysis, 4 January 1961, 00 GCT, of LMW wind speeds (mps, isotachs labelled with slanting numbers) and directions (thin arrows) obtained from grid-point data. For comparison, station data for wind speeds are entered in vertical numbers, for wind directions by heavy dashes and dots. The heavy dashed lines with arrows indicate the position of jet axes.

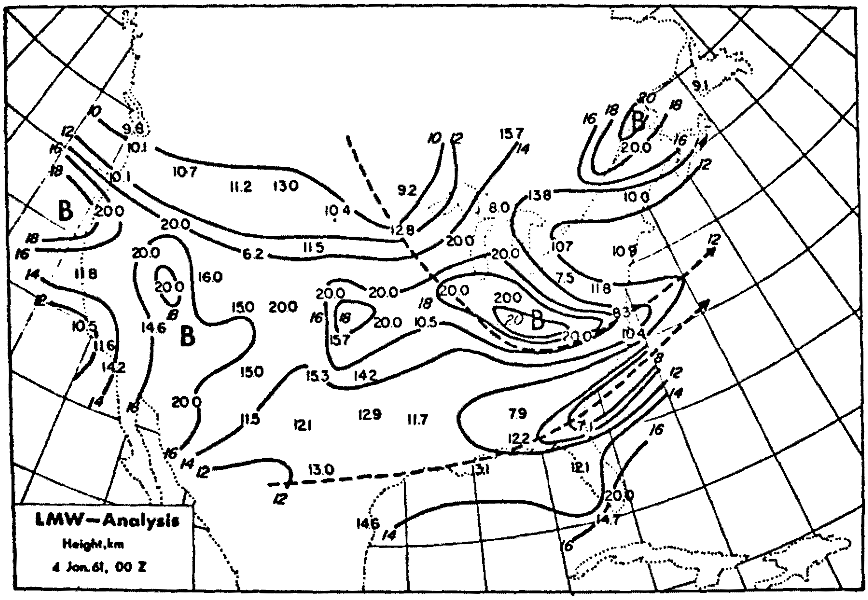


Fig. 6: Objective analysis, 4 January 1961, 00 GCT, of LMW heights (km, isolines labelled with slanting numbers) obtained from grid-point data. For comparison, station data are entered in vertical numbers. B indicates barotropic regions. Jet axes as in Fig. 5.

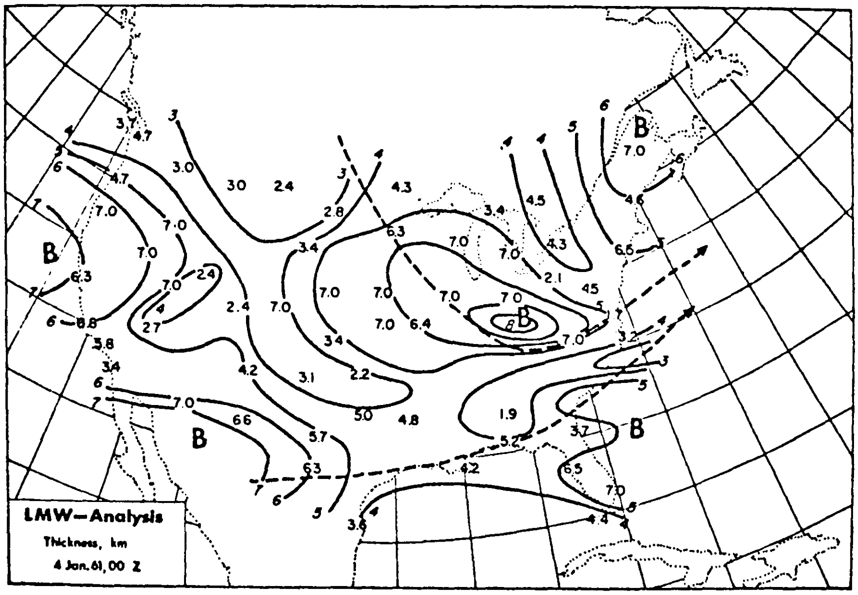


Fig. 7: Objective analysis, 4 January 1961, 00 GCT, of LMW thicknesses (km, isolines labelled with slanting numbers) obtained from grid-point data. For comparison, station data are entered in vertical numbers. B indicates barotropic regions. Jet axes as in Fig. 5.

IV. Forecasting the Layer of Maximum Wind

The forecasts of the LMW parameters described in the following are all based on the kinematic extrapolation equations (Reiter 1962a).

$$\frac{\partial u}{\partial t} = -c_x \frac{\partial u}{\partial x} - c_y \frac{\partial u}{\partial y}$$

$$\frac{\partial v}{\partial t} = -c_x \frac{\partial v}{\partial x} - c_y \frac{\partial v}{\partial y} \qquad (1)$$

c_x and c_y are components of displacement of the isotach system.

From equ. (1) the displacement speeds may be evaluated:

$$c_x = \frac{\frac{\partial u}{\partial y} \cdot \frac{\partial v}{\partial t} - \frac{\partial v}{\partial y} \cdot \frac{\partial u}{\partial t}}{D}$$

$$c_y = \frac{\frac{\partial u}{\partial x} \cdot \frac{\partial v}{\partial t} + \frac{\partial v}{\partial x} \cdot \frac{\partial u}{\partial t}}{D} \qquad (2)$$

$$D = \frac{\partial u}{\partial x} \cdot \frac{\partial v}{\partial y} - \frac{\partial u}{\partial y} \cdot \frac{\partial v}{\partial x}$$

Instead of the differentials in equs. (1) and (2) we will have to use finite differences in the numerical forecasts. First, Δu and Δv are evaluated between map times $t = t_o$ and $t = (t_o - \Delta t)$. After the difference form of equ. (2) yields c_x and c_y, the numerical values of these displacement velocities are entered again into equ. (1). Δu and Δv for the time interval between $t = t_o$ and $t = (t_o + \Delta t)$, added to the original values u and v observed at $t = t_o$, render the forecast wind field.

It has been pointed out in an earlier report (Reiter 1962a), that under the assumption c_x = const. and c_y = const. during the time interval Δt, the wind field should not intensify. Jet stream systems may weaken under these simple kinematic assumptions, if the isotachs to the rear of a jet maximum move faster than the ones in front of the maximum. Kinematic extrapolation is not able, however, to generate new isotachs of higher wind speeds. If such high-velocity jet stream cores were generated during the forecasting process, this would be entirely due to truncation errors. These errors are produced by using finite differences rather than differentials (Sundqvist 1963). A second source of forecasting errors lies in the assumption of c_x and c_y to be constant. A third source of forecasting errors - probably the most critical one - lies in the errors of the analyses on which the forecasts were based.

It has been shown in the earlier report that truncation terrors may be quite appreciable, both in interpolation between and in extrapolation from two basic observation times. (Fig. 8) shows the truncation errors produced in the amplitudes of a sinusoidal wave pattern progressing with speed c (grid units per hour) along the x axis of a rectangular grid as shown in Fig. 4. Values at time $t = 0$ and $t = 12$ are used to arrive at hourly interpolations and extrapolations up to a 12 hour forecast for $t = 24$.

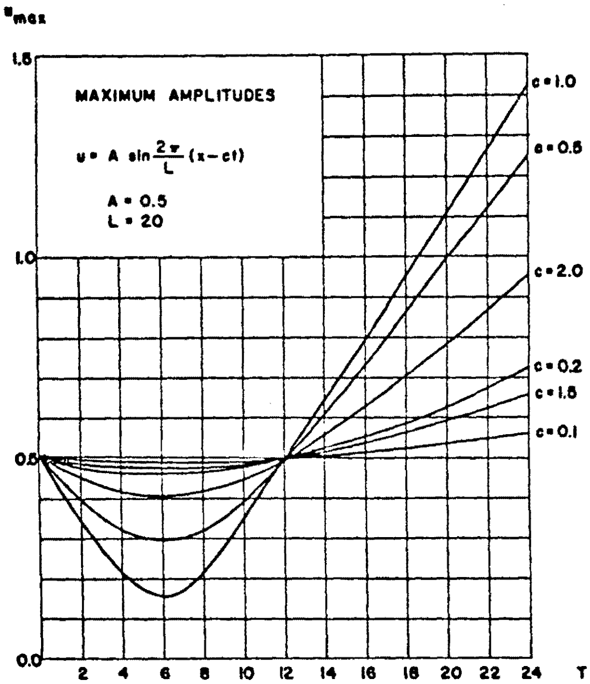


Fig. 6: Maximum wind speeds (u_{max} in grid units per hour) of a sinusoidal wave pattern of wave length L = 20 grid units as a function of time (hours), computed for various wave speeds (c in grid units per hour). Interpolation between values given at T=0 and T=12, extrapolation to T =24, in hourly intervals.

Since in first approximation the jet stream pattern over the continental United States may be considered a wave pattern of quasi-sinusoidal shape, appreciable truncation errors will have to be expected for extrapolations of waves with certain speeds. The various approaches taken in the following to forecast the wind field in the LMW were mainly aimed at the reduction of such truncation errors.

Persistence "forecasts" have been used as a basis for evaluation of the skill of the numerical forecasts. As has been known before (Barbé 1957; Reiter 1961, 1963b), and as became again evident during these studies, the 12 - and even the 24-hour changes of the wind field in the jet stream region are relatively small. Persistence "forecasts" - stating that the mean winds of the LMW will remain constant during the period of the forecast -- have approximately the same order of magnitude of error as kinematic extrapolation forecasts of the LMW. This may be explained by the fact, that the LMW describes the mean flow conditions of a relatively deep atmospheric layer. In doing so, the LMW parameters, especially the mean wind speeds and wind directions of this layer become representative indicators which are less sensitive to local variations of flow in time and space than spot-winds measured at a particular level might be.

Thickness and height of the LMW, which describe the conditions of vertical wind shear above and below the jet-core level should be expected to be less conservative in time, especially in the vicinity of the jet axis. Persistence forecasts of these quantities, therefore, are expected to give relatively poor performances.

Naturally, the quality of forecasts will be rather sensitive to inaccuracies in the analyses on which the forecast is based. The fitting of a quadratic surface to station data in order to arrive at grid-point representation of the LMW parameters has several disadvantages, such as the tendency of generating circular isotach patterns rather than oblong ones. Objective analysis methods proposed by Bergthorsson and Döös (1955) and Cressman (1959), which are based upon a first approximation of the wind field and subsequent improvements of this "first guess", may ultimately yield better results in LMW representation, and consequently also in its forecasts. For lack of time such procedures could not be tried during this research program. Offhand, it would appear, that the 250 - or 300-mb (geostrophic) wind obtainable from an objective analysis of such a pressure level, could be used as a first approximation to the LMW winds.

Geostrophic winds at these levels, obtained from a baroclinic forecast, could probably be used to advantage in improving the kinematic forecasting techniques, by again imposing certain restrictions upon the computed changes of LMW parameters, using the forecast geostrophic wind field as a first approximation. Experiments of this kind, too, will have to be left to future research.

(1) The Effect of Smoothing of Input Data Upon the Quality of Forecasts

Appendix 5 contains the flow diagram, symbol lists and program of 12 h extrapolation forecasts based upon simple kinematic extrapolation according to equs. (1) and (2). In order to estimate the effect of "noise" in the input data, this forecasting procedure has been applied to "smoothed" as well as to "unsmoothed" input analyses. As described in Chapter III, the smoothing consisted of a second scanning of station and grid point data, whereby the latter -- obtained from a first scan of station data -- were now considered equivalent to "new" stations reporting observations.

Results of these forecasts using unsmoothed and smoothed data, are reported in Tables I and IIa, which give values of mean wind speed $\overline{VV}$ and mean direction dd of the LMW at all grid points shown in Fig. 4. In addition, mean errors of the forecast wind speeds and wind directions obtained from comparisons with the actual grid point values at verification time are shown. For comparison, Table IIb contains the errors resulting from a persistence forecast.

As may be seen from these tables, the smoothed input analyses produce better forecasting results than the unsmoothed ones.

(2) 12 and 24-hour forecasts

Experiments with 12 - and 24-hour forecasts, derived from smoothed and unsmoothed input data, showed that 24-hour extrapolations produce usable results only in a one-step computation of the wind changes from the time period (t_o, t_o -24) hours to the interval (t_o, t_o + 24) hours. Two-step extrapolations from (t_o, t_o -12) hours to (t_o, t_o + 12) hours and from there to (t_o + 24) hours by applying the computed values of c_x and c_y (equ. 2) for 12-hour time steps twice in succession proved to be unsatisfactory. The truncation errors as shown in Fig. 8 reduce the quality of the forecast below the level achieved by persistence.

The program for a direct 24-hour forecast is given in Appendix 5. Results for the same day as shown in Table I and II are presented in Table III.

In view of these findings, it was decided to arrive at 12-hour forecasts by interpolation of 24-hour forecasts, applying one half of the values of c_x and c_y computed for a 24-hour extrapolation interval. As may be seen from Table IV, a better quality of forecasts was achieved by this procedure. Programs for such 12-hour kinematic interpolations, again, are listed in Appendix 5. An example is given in Table IV.

(3) Reduction of Truncation Errors by Scanning Procedures

As has been pointed out earlier, a kinematic forecast should not be able to show increases in maximum wind speeds because "new" isotachs cannot be generated by a simple advective technique. Strong increases in speeds along the jet core, as they are observed in several of the forecasting examples listed above, are due to truncation errors.

To reduce the effects of errors, a scanning procedure has been devised, operating in the following fashion: The basic map at t = 0 is scanned along the horizontal grid lines for "major" maxima and minima in u and v components. In order to eliminate the "minor" maxima and minima produced by noise in the data especially in regions at some distance from the jet axis, a minimum separation of 10 mps between adjacent wind maxima and minima was specified. Only wind fluctuations along horizontal grid lines which qualified beyond this threshold value were retained as significant.

Then the forecast map (t_o + 24) hours was scanned in the same fashion,

	.														.
.	215/55 9/-22	228/46 4/-11	.	.	.	.	.	.	.	.	.	281/26 10/1	264/28 6/-0	257/27 -11/6	.
.	204/44 0/-15	215/33 1/-9	225/25 12/-2	265/27 6/-2	.	.	.	.	.	323/37 11/3	289/28 29/2	264/30 43/-3	256/42 17/-14	256/46 -10/-8	.
.	208/45 -3/24	203/29 13/-12	233/37 -2/-22	255/37 13/-20	352/14 -42/6	339/36 -13/0	10/60 -35/-21	8/70 -28/-24	4/62 -23/-23	349/37 -16/0	262/39 52/-3	252/45 52/-11	248/56 26/-21	248/65 4/-20	.
.	190/31 26/-16	183/20 47/-7	197/18 50/-7	243/20 36/-6	16/6 -76/9	355/26 -36/3	27/55 -60/-25	21/63 -50/-26	12/53 -47/-18	343/27 -24/11	251/37 54/1	246/52 53/-12	244/66 29/-23	243/74 12/-20	.
.	144/20 106/-5	176/14 80/0	187/13 98/2	250/16 28/1	292/10 -2/7	17/13 -82/8	29/38 -87/-13	17/52 -65/-19	7/41 -59/-5	313/23 -13/17	246/36 44/5	243/59 42/-16	241/75 31/-25	244/85 15/-28	.
.	79/3 -176/20	.	219/12 59/11	244/21 24/3	259/20 6/2	280/15 -7/9	357/23 -76/3	354/25 -70/7	317/24 -35/14	283/28 2/16	252/44 24/5	247/65 19/-3	243/77 20/-12	245/90 13/-26	.
.	.	.	.	.	259/35 -0/-5	269/24 -6/6	312/25 -44/8	309/35 -33/2	290/42 -16/2	294/42 -18/7	255/53 14/6	249/61 17/-0	245/63 18/0	244/69 15/-0	.
.	.	.	.	.	.	.	291/48 -20/-3	291/33 -19/13	276/62 -5/-12	273/72 -4/-21	.	260/47 1/17	256/55 5/12	250/56 8/6	.
						.	.	.	263/27 7/27	.	.	.	.	.	.
								.							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
2 January 00GCT	27.2/8.8
2 January 12GCT	16.9/8.6
3 January 00GCT	17.7/10.2
3 January 12GCT	28.9/12.5
4 January 00GCT	35.4/8.8
4 January 12GCT	11.8/10.2

Table I: Direct kinematic 12 hour forecast at grid points verifying 4 January, 1961, 00 GCT; no smoothing on input data or forecast. Forecast directions and speeds. (dd/vv), differences between actual and forecast directions and speeds at grid points. (Edd/Evv), as indicated in plotting model.

	•														232/26 1/12
•	210/50 11/-18	225/43 5/-11	247/39 2/-6	•	•	•	•	•	•	335/47 -10/-8	300/29 16/2	277/26 16/0	262/26 7/0	252/28 -7/5	•
189/50 [illegible]5/-26	205/45 3/-18	218/36 0/-11	235/32 5/-10	265/30 8/-5	298/35 3/-2	•	•	•	353/66 -17/-21	333/39 -0/-0	290/28 30/3	266/34 40/-6	256/42 16/-14	255/45 -8/-8	•
187/46 18/-28	198/40 6/-20	204/31 9/-13	229/31 4/-16	253/28 18/-12	313/16 -6/5	347/33 -22/0	9/56 -35/-17	8/69 -29/-26	2/58 -25/-17	343/35 -13/3	271/32 45/2	251/43 51/-10	250/55 25/-20	248/65 5/-21	•
172/35 [illegible]/-21	184/29 32/-14	185/22 46/-9	199/19 51/-7	238/16 40/-2	336/7 -34/10	5/26 -45/0	24/51 -57/-20	19/62 -48/-26	10/50 -44/-14	336/26 -16/11	258/32 49/5	246/52 47/-13	243/68 30/-25	245/74 11/-22	•
•	169/17 80/-1	165/15 92/-0	190/12 84/3	242/15 33/1	287/7 0/11	16/16 -78/5	23/36 -79/-10	17/49 -67/-17	4/39 -56/-3	314/21 -14/18	250/37 40/5	244/59 37/-13	242/73 28/-21	244/83 13/-23	•
•	257/10 1/13	233/10 29/12	224/13 48/9	242/21 25/1	258/16 10/6	294/12 -19/12	358/21 -76/6	359/29 -72/3	326/27 -40/10	282/31 1/13	252/46 24/3	246/62 25/-6	243/75 22/-14	242/83 16/-17	•
•	•	•	255/24 11/5	254/30 6/-1	264/30 -2/-0	273/29 -8/2	305/27 -36/7	311/31 -35/7	291/34 -16/9	275/46 -1/3	256/52 13/4	249/60 18/-0	246/66 18/-3	245/70 13/-2	•
•	•	•	•	•	271/49 -10/-12	280/50 -13/-9	289/44 -19/-0	289/43 -17/3	280/48 -8/1	274/51 -3/2	258/53 7/6	257/51 5/13	252/54 9/10	249/55 10/7	•
						•	280/58 -12/-8	272/48 -1/3	270/46 -0/6	265/52 2/2	261/42 2/16	261/46 0/13	263/43 -1/15	258/41 2/11	•
								•							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
2 January 00GCT	24.7/8.0
2 January 12GCT	15.3/7.0
3 January 00GCT	16.7/9.4
3 January 12GCT	28.5/11.4
4 January 00GCT	23.4/9.5
4 January 12GCT	11.1/9.4

Table IIa: Direct kinematic 12 hour forecast at grid points verifying 4 January, 1961, 00 GCT; smoothing on input data by double scanning of analysis; no smoothing on forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

	6/-1 5/-1														-10/2 -10/1
19/-2 20/-2	5/4 2/5	-14/9 -15/9	-25/7 -30/7	-29/3 -30/2	. -21/-1	.	.	.	. -4/6	11/7 13/7	42/3 38/4	30/-5 33/-6	17/-10 17/-10	-4/-6 -4/-6	-16/-5 -16/-5
25/1 24/0	1/11 5/9	-23/15 -23/14	-58/13 -53/9	-55/2 -50/2	-35/-2 -34/-2	-17/1 -20/0	-20/-3 -19/-3	-9/1 -10/0	-1/3 0/5	33/13 26/11	46/3 48/3	51/-8 49/-9	22/-17 21/-17	-5/-12 -4/-12	-20/-8 -19/-8
32/-5 35/-3	15/6 28/6	56/14 41/14	-68/6 -80/8	-56/-2 -63/-1	-54/-7 -47/-5	-24/-2 -27/-3	-23/-6 -22/-4	-13/1 -12/0	4/4 2/7	24/11 25/12	54/-2 53/0	52/-11 50/-11	25/-18 25/-18	3/-15 4/-16	-13/-7 -13/-6
83/-12 70/-4	54/3 65/4	133/7 123/7	-146/6 -145/7	-71/2 -77/2	-66/-3 -56/-2	-31/0 -33/-2	-30/-4 -28/-2	-18/2 -17/1	-2/6 -1/7	25/12 29/10	49/-3 48/-1	47/-14 41/-14	23/-19 24/-19	6/-13 6/-15	-8/0 -8/-2
78/10 67/9	119/6 97/9	168/12 158/11	-125/11 -115/12	-52/8 -52/8	-41/4 -44/5	-33/4 -33/3	-33/2 -28/2	-14/4 -15/4	0/8 2/8	20/8 22/7	35/-2 33/-2	33/-15 29/12	22/-18 20/-15	8/-17 6/-13	-9/7 -6/1
-5/1 -3/0	-9/16 -8/11	-11/13 -7/13	11/16 2/14	-9/10 -8/8	-12/3 -12/5	-5/1 -8/2	-12/2 -10/3	-2/3 -3/4	6/3 6/3	16/5 15/3	19/-1 19/-2	13/-3 18/-7	12/-6 14/-9	6/-12 7/-7	-7/17 -4/5
.	-11/-8 -10/-7	. -5/3	11/11 3/6	-6/1 -3/2	-6/-3 -5/-1	-1/-5 -1/-5	-4/-3 -2/-3	3/-5 4/-2	6/-3 8/-1	4/4 10/-1	14/1 13/0	13/-2 14/-2	11/0 12/-2	7/4 6/3	7/-5 0/7
.	.	.	. 0/3	. -2/-3	-4/-9 -2/-9	5/-10 4/-9	7/-7 7/-7	13/-1 10/-5	10/-8 11/-3	7/-11 11/-1	12/-2 11/1	6/8 8/7	7/9 8/7	5/7 6/8	. 0/11
						. 6/-12	9/-9 9/-8	18/-1 17/-5	22/4 16/-2	10/-2 13/-1	. 10/7	6/9 7/7	5/11 5/11	5/6 4/11	-1/8 0/9
								. 16/-4							

Plotting model:

UEdd/UEvv SEdd/SEvv

Verifying Date	Average Error UEdd/UEvv	SEdd/SEvv
2 January 00GCT	13.6/5.6	12.7/5.3
2 January 12GCT	14.1/6.0	13.6/5.6
3 January 00GCT	22.3/6.6	19.4/6.1
3 January 12GCT	28.2/9.2	27.3/8.4
4 January 00GCT	25.3/6.6	23.2/6.0
4 January 12GCT	16.8/7.4	15.1/7.1

Table IIb: Errors made by "persistence" forecast, verifying at 4 January, 1961, 00 GCT. Differences between actual and 12 hour old directions and speeds, no smoothing on input data (UEdd/UEvv), and smoothing on input data by double scanning of analysis (SEdd/SEvv), as indicated in plotting model.

	.													
.	189/36 35/-3	225/22 7/12	.	.	.	.	.	.	.	.	.	244/41 47/-13	242/49 28/-21	239/60 6/-26
.	147/21 57/7	67/20 149/3	37/32 -159/-9	25/62 -113/-37	.	.	.	.	.	294/17 40/23	261/20 57/10	235/39 72/-12	232/59 41/-31	233/72 12/-34
.	91/48 113/-27	65/50 151/-33	51/65 179/-50	41/83 -132/-66	29/75 -79/-54	15/76 -49/-39	355/56 -20/-17	340/43 -0/2	305/30 35/8	289/28 43/9	257/29 57/6	236/43 68/-9	232/55 42/-20	239/65 13/-20
.	86/47 130/-32	65/54 165/-41	52/64 -164/-53	47/78 -127/-64	35/63 -95/-47	14/61 -55/-31	325/43 1/-13	309/44 21/-7	284/41 40/-6	287/36 31/2	265/44 40/-5	250/58 49/-18	243/61 30/-18	247/68 8/-14
.	77/29 173/-14	60/44 -163/-29	56/61 -130/-45	49/64 -130/-46	39/48 -109/-30	351/34 -56/-12	303/37 -1/-12	281/48 30/-15	278/47 29/-11	284/42 15/-1	274/46 16/-4	265/62 20/-19	259/71 13/-21	260/74 -0/-17
.	282/7 -19/16	.	47/27 -128/-3	36/35 -127/-10	11/19 -105/3	296/21 -23/3	268/40 12/-13	266/55 17/-22	266/52 15/-13	276/52 9/-7	271/62 5/-12	264/74 2/-12	264/77 -0/-12	269/74 -10/-10
.	.	.	.	.	287/19 -28/10	258/49 4/-18	250/63 17/-29	250/68 25/-30	251/62 22/-17	258/52 17/-2	255/69 14/-10	257/74 9/-13	259/76 4/-12	263/70 -3/-1
.	.	.	.	.	.	.	229/78 41/-33	235/92 36/-45	234/65 36/-15	239/59 29/-8	249/80 14/-21	246/78 15/-13	246/72 15/-4	254/62 4/0
						.	.	.	237/103 33/-48	234/65 32/-10	237/62 26/-3	241/77 21/-17	233/47 29/11	239/34 23/12
								.						

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
3 January 00GCT	32.2/14.5
3 January 12GCT	38.4/21.3
4 January 00GCT	49.6/18.8
4 January 12GCT	58.5/16.3

Table IIIa: Direct kinematic 24 hour forecast at grid points verifying 4 January, 1961, 00 GCT; no smoothing on input data or forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

	.														274/68 -40/29
.	202/34 19/-2	225/15 5/16	325/21 -75/11	.	.	.	.	.	.	289/25 35/13	263/22 53/9	247/39 46/-12	243/52 26/-25	247/63 -2/-29	.
184/23 30/0	132/21 76/5	67/19 151/5	38/37 -157/-15	26/62 -112/-37	19/79 -77/-46	.	.	.	312/28 23/16	290/20 42/18	258/24 62/7	235/38 71/-10	232/56 40/-28	237/67 9/-30	.
[illegible]06/36 [illegible]/-18	91/42 113/-22	66/49 147/-31	51/62 -177/-47	40/77 -128/-61	29/78 -82/-56	14/71 -49/-37	354/55 -20/-16	333/39 5/3	306/30 30/10	286/27 43/11	254/30 62/4	239/43 63/-10	233/57 42/-22	238/65 15/-21	.
[illegible]/37 [illegible]/-23	83/46 133/-31	65/55 166/-42	53/65 -162/-53	46/76 -127/-62	32/65 -90/-47	12/57 -52/-30	332/41 -5/-10	310/42 20/-6	290/39 35/-3	284/35 35/2	267/40 40/-2	251/53 42/-14	245/59 28/-16	248/67 8/-15	.
.	79/33 170/-17	61/42 -163/-27	54/55 -139/-39	48/60 -132/-43	34/49 -106/-30	351/34 -53/-12	306/36 -2/-10	285/46 24/-14	279/46 28/-10	280/45 19/-5	273/50 17/-7	263/61 18/-15	257/68 13/-16	260/73 -2/-13	.
.	324/3 -65/20	39/16 -136/6	44/28 -131/-5	34/32 -126/-9	10/21 -101/1	301/24 -26/0	270/42 11/-14	264/56 22/-23	268/52 17/-14	273/52 10/-7	270/60 6/-10	264/71 7/-15	263/76 2/-15	268/76 -9/-10	.
.	.	.	310/12 -43/17	315/14 -54/14	278/19 -16/10	257/41 7/-9	249/60 19/-25	250/68 25/-29	252/64 22/-20	256/57 17/-7	258/65 11/-8	257/72 10/-12	259/73 5/-10	263/68 -4/-0	.
.	.	.	.	.	244/41 16/-4	232/58 34/-17	232/79 37/-35	236/84 35/-37	239/73 32/-23	242/67 28/-13	247/75 18/-15	246/74 16/-9	247/70 14/-5	255/59 4/3	.
						.	223/78 44/-28	229/88 41/-36	233/82 36/-29	237/69 30/-14	239/70 24/-11	237/67 24/-7	236/56 25/2	240/40 20/12	.
								.							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
3 January 00 GCT	30.7/13.4
3 January 12 GCT	38.8/20.1
4 January 00 GCT	51.0/17.9
4 January 12 GCT	51.6/15.8

Table IIIb: Direct kinematic 24 hour forecast at grid points verifying 4 January, 1961, 00 GCT; smoothing on input data, no smoothing on forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

	.														.
.	210/53 14/-20	224/49 8/-14	.	.	.	.	.	.	.	.	.	262/28 29/-0	244/32 26/-4	235/36 10/-2	.
.	198/42 6/-13	206/29 10/-5	220/20 17/2	293/18 -21/6	.	.	.	.	.	322/33 12/7	288/25 30/5	262/29 45/-2	249/40 24/-12	242/47 3/-9	.
.	192/37 12/-16	183/22 33/-5	219/18 11/-3	288/14 -19/2	21/31 -71/-10	3/51 -37/-14	10/64 -35/-25	6/67 -26/-21	352/49 -11/-10	334/34 -1/3	271/36 43/-0	259/42 45/-8	250/52 24/-17	246/62 6/-17	.
.	168/29 48/-14	138/18 92/-5	131/12 116/-1	38/10 -118/3	38/27 -98/-11	13/42 -54/-12	18/52 -51/-22	11/53 -40/-16	355/39 -30/-4	325/28 -6/10	265/39 40/-0	258/54 41/-14	251/64 22/-21	247/72 8/-18	.
.	131/21 119/-6	119/14 137/0	95/15 -169/0	37/10 -118/7	23/16 -93/1	15/22 -80/-0	13/32 -71/-7	357/38 -45/-5	343/30 -35/5	301/27 -1/13	258/37 32/4	254/57 31/-14	250/72 22/-22	249/83 10/-26	.
.	109/1 153/22	.	145/2 133/21	300/6 -31/18	301/10 -35/12	302/13 -29/11	332/20 -51/6	315/22 -31/10	293/27 -11/11	279/29 6/15	257/42 19/7	252/63 14/-1	248/73 15/-8	248/83 10/-19	.
.	.	.	.	.	271/26 -12/3	268/28 -5/2	285/29 -17/4	284/36 -8/1	275/41 -1/3	282/36 -6/13	254/51 15/7	251/60 15/0	248/63 15/0	247/67 12/1	.
.	.	.	.	.	.	.	271/48 -0/-3	264/43 7/3	264/57 6/-7	263/63 5/-12	.	254/53 7/11	251/57 10/10	247/56 11/6	.
						.	.	.	248/48 22/6	.	.	.	.	.	.
								.							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
2 January 12GCT	15.0/6.3
3 January 00GCT	18.2/9.7
3 January 12GCT	27.1/12.5
4 January 00GCT	35.3/8.9

Table IVa: Interpolated kinematic 12-hour forecast at grid points verifying 4 January, 1961, 00 GCT, using ½ C_x and ½ C_y computed from 24-hour pattern displacement; no smoothing on input data or forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

	.														232/45 1/-6
.	209/50 12/-18	221/44 9/-12	245/40 4/-7	.	.	.	.	.	.	323/40 1/-1	290/28 26/3	260/29 33/-2	244/32 25/-5	236/39 8/-5	.
193/46 21/-22	198/42 10/-15	209/31 9/-6	232/23 8/-1	290/19 -16/5	333/34 -31/-1	.	.	.	348/55 -12/-10	326/34 6/4	288/27 32/4	263/32 43/-4	249/40 23/-12	244/46 2/-9	.
180/41 25/-23	183/35 21/-15	182/23 31/-5	209/13 24/1	306/9 -34/6	8/28 -61/-6	5/47 -40/-13	9/61 -35/-22	4/63 -25/-20	353/48 -16/-7	330/32 -0/6	277/32 39/2	257/40 45/-7	251/52 24/-17	246/62 7/-18	.
164/33 [illegible]1/-19	161/26 55/-11	143/19 88/-6	127/12 123/-0	46/10 -127/3	27/25 -85/-7	16/41 -56/-14	16/50 -49/-19	9/53 -38/-17	354/39 -28/-3	320/28 -0/9	270/34 37/3	257/52 36/-13	249/63 24/-20	249/72 7/-20	.
.	143/18 106/-2	120/16 137/-1	97/13 177/2	45/8 -129/8	25/17 -97/1	15/25 -77/-3	9/33 -65/-7	358/36 -48/-4	341/30 -33/5	298/26 1/13	261/38 29/4	253/56 28/-10	250/70 20/-18	249/80 8/-20	.
.	251/7 7/16	222/3 40/19	164/1 108/21	290/5 -22/17	317/8 -48/14	316/14 -41/10	331/19 -49/8	322/23 -35/9	301/27 -15/10	277/32 6/12	257/45 19/4	252/60 19/-4	248/71 17/-10	247/78 11/-12	.
. .	. .	. .	268/19 -1/10	269/21 -8/7	275/24 -13/5	273/29 -8/2	283/29 -14/5	284/33 -8/5	274/37 0/6	267/44 6/5	255/51 14/5	251/58 16/1	248/64 16/-1	247/67 11/0	.
.	.	.	.	.	269/44 -8/-7	269/46 -2/-5	269/46 0/-2	268/48 3/-1	265/49 6/0	262/51 8/2	253/56 12/3	252/55 10/9	250/56 11/8	247/54 12/8	.
						.	264/56 3/-6	256/55 14/-3	255/54 14/-1	255/56 12/-1	252/50 11/8	253/52 8/7	255/46 6/12	252/40 8/12	.
								.							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
2 January 12GCT	13.6/5.0
3 January 00GCT	17.8/9.1
3 January 12GCT	27.8/11.3
4 January 00GCT	29.6/8.2

Table IVb: Interpolated kinematic 12 hour forecast at grid points verifying 4 January, 1961, 00 GCT, using ½ C_x and ½ C_y computed from 24-hour pattern displacement; smoothing on input data, no smoothing on forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

and forecast maxima (and minima) of the u and v components were adjusted to their original magnitude.

This scanning technique usually failed to reduce truncation errors in the Pacific Northwest of the United States, because the two northernmost grid lines were not fully covered with data, and therefore did not permit the required estimate of maximum and minimum values of LMW parameters.

Examples of 24-hour forecasts obtained with this scanning procedure are given in Table V. Programs are listed in Appendix 6.

Two different twelve-hour forecasts were tested:

(a) Applying half of the observed 24-hour changes derived with above scanning procedure at individual gridpoints.

(b) 12-hour extrapolation of the time interval (t_0 - 12) hours applying above scanning procedure directly to the 12-hour results.

A sample of results is presented in Table VI. It shows the interpolation from 24-hour forecasts to be of slightly better quality than direct 12-hour extrapolation. Programs, again are listed in Appendix 6.

(4) Geostrophic Steering of the LMW

A different approach, trying to compute a possible correlation of LMW displacements from the 300-mb geostrophic steering current has been tried by Rasmussen (1963). No significant correlation could be found between the components u_g and v_g of the 300-mb geostrophic wind, and the rates of displacement, c_x and c_y, of LMW isotach systems. Apparently, a certain relationship exists only between the speed of propagation of jet maxima and the geostrophic wind of the 300-mb level (Reiter 1958).

Tests were also made by Rasmussen (1963), incorporating a climatic value of 12^o longitude per day (Namias 1947) for the advection of isotach systems in the x-direction of the grid. Again, no significant correlation could be found between the remaining displacement speed of isotachs in the y-direction, c_y, and the 300-mb geostrophic wind.

(5) Forecasting Thickness and Height of the LMW

It turned out, that the smoothing technique described earlier for wind speed and direction analyses was not directly applicable to the parameters $\bar{h}$ and Δ h, height and mean thickness, of the LMW. This was mainly due to the fact that standard values of $\bar{h}$=20 km and Δ h=7 km were assigned to barotropic wind profiles reported at individual stations. When computing gridpoint values by fitting a quadratic surface to station values, and especially when re-evaluating grid data by considering them equivalent to station data in a second run of the program, these assigned "barotropic" values tended to overpower non-baratropic values near the observed jet axes, thus rendering a rather smooth field

	.														.
.	214/10 10/22	302/19 -69/15	.	.	.	.	.	.	.	.	.	270/37 21/-9	242/49 28/-21	239/60 6/-26	.
.	70/12 134/16	29/38 -172/-14	20/57 -142/-34	17/90 -105/-65	.	.	.	.	.	341/51 -6/-10	261/20 57/10	235/39 72/-12	232/59 41/-31	233/72 12/-34	.
.	76/18 128/2	35/17 -178/-0	25/31 -154/-16	18/45 -109/-28	42/55 -92/-34	25/47 -59/-10	353/37 -18/1	332/31 7/14	293/27 47/11	287/27 45/10	266/28 48/7	250/38 54/-4	248/47 26/-12	239/65 13/-20	.
.	88/12 128/2	42/15 -171/-2	21/25 -133/-14	23/37 -103/-23	1/29 -61/-13	333/37 -14/-7	290/55 36/-25	286/60 44/-23	273/59 51/-24	281/50 37/-11	270/55 35/-16	260/62 39/-22	257/59 16/-16	247/67 8/-13	.
.	281/2 -30/12	359/9 -102/5	27/20 -101/-4	33/27 -114/-9	1/22 -71/-4	305/38 -10/-16	281/54 20/-29	272/65 39/-32	271/61 36/-25	278/51 21/-10	273/52 17/-10	267/63 18/-20	262/68 10/-18	259/67 0/-10	.
.	282/7 -19/16	.	47/27 -128/-3	36/35 -127/-10	11/19 -105/3	296/21 -23/3	268/40 12/-13	258/15 25/17	283/10 -1/28	329/16 -43/28	275/29 1/20	257/47 9/14	262/55 1/9	269/74 -10/-10	.
.	.	.	.	.	264/27 -5/2	256/51 6/-20	250/61 17/-27	252/61 23/-23	255/59 18/-14	264/53 11/-3	260/64 9/-5	261/65 5/-4	263/64 0/-0	269/69 -9/-0	.
.	.	.	.	.	.	.	217/64 53/-19	230/81 41/-34	231/61 39/-11	239/59 29/-8	261/64 2/-5	246/77 15/-12	246/72 15/-4	254/62 4/0	.
						.	.	.	249/92 21/-37	246/58 20/-3	247/60 16/-1	245/75 17/-15	234/47 28/11	234/36 28/10	.
								.							

Plotting model:

dd/vv Edd/Evv

Verifying Date	Average Error Edd/Evv
3 January 00GCT	28.7/10.0
3 January 12GCT	39.0/14.9
4 January 00GCT	45.7/14.5
4 January 12GCT	57.3/12.8

Table Va: Direct kinematic 24 hour forecast at grid points verifying 4 January 1961, 00 GCT; no smoothing on input data, smoothing on forecast by scanning for maxima and minima. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

															274/68 -40/-29
.	[illegible]/17 -3[illegible]/14	310/18 -79/13	340/39 -90/-6	.	.	.	.	.	.	290/25 34/13	263/22 53/9	247/39 46/-12	243/52 26/-25	244/54 0/-20	.
[illegible]	[illegible]/19 157/7	27/38 -168/-13	22/61 -141/-39	18/87 -104/-62	14/105 -72/-72	.	.	.	336/51 -0/-6	290/20 42/18	258/24 62/7	235/38 71/-10	232/56 40/-28	237/67 9/-30	.
81/35 124/-17	87/42 117/-22	69/48 144/-30	58/57 175/-42	49/67 -137/-51	38/60 -91/-38	23/46 -58/-12	352/39 -18/-0	324/30 14/12	298/27 38/13	287/27 42/11	266/29 50/5	254/39 48/-6	249/49 26/-14	238/65 15/-21	.
36/37 139/-23	84/46 132/-31	71/53 160/-40	60/59 -169/-47	14/39 -95/-25	357/35 -55/-17	327/39 -7/-12	307/60 19/-29	295/63 35/-27	283/58 42/-22	280/51 39/-13	268/52 39/-14	254/60 39/-21	246/62 27/-19	247/66 9/-14	.
.	89/33 160/-17	75/38 -177/-23	66/48 -151/-32	355/24 -79/-7	336/24 -48/-5	299/43 -1/-21	281/58 22/-32	273/68 36/-36	272/64 35/-28	275/58 24/-18	272/58 18/-15	266/64 15/-18	261/66 9/-14	259/66 -1/-6	.
.	257/15 1/8	281/13 -18/9	314/11 -41/11	346/13 -78/9	302/17 -33/5	274/36 0/-11	261/54 20/-26	258/66 28/-33	261/58 24/-20	267/54 16/-9	266/59 10/-9	261/67 10/-11	261/68 4/-7	267/65 -8/0	.
.	.	.	250/9 16/20	292/10 -31/18	268/19 -6/10	256/41 8/-9	251/59 17/-24	254/66 21/-27	257/63 17/-19	262/56 11/-6	263/64 6/-7	261/71 6/-11	253/28 11/34	265/24 -6/43	.
.	.	.	.	.	262/33 -1/3	245/43 21/-2	242/63 27/-19	232/78 39/-31	239/73 32/-23	242/67 28/-13	247/75 18/-15	246/74 16/-9	247/70 14/-5	255/59 4/3	.
						.	235/56 32/-6	245/68 25/-16	253/65 16/-12	264/55 3/-0	268/57 -4/1	237/67 24/-7	236/56 25/2	240/40 20/12	.
								.							

Plotting model:

dd/vv
Edd/Evv

Verifying Date	Average Error Edd/Evv
3 January 00GCT	28.5/9.6
3 January 12GCT	39.8/17.5
4 January 00GCT	46.4/17.9
4 January 12GCT	42.1/9.1

Table Vb: Direct kinematic 24 hour forecast at grid points, verifying 4 January 1961, 00 GCT; smoothing on input data and forecast. Forecast directions and speeds (dd/vv), differences between actual and forecast directions and speeds (Edd/Evv), as indicated in plotting model.

	•														•
•	205/49 232/40	226/46 251/36	•	•	•	•	•	•	•	•	•	262/28 310/34	251/43 264/28	234/37 257/27	•
•	195/20 219/29	224/11 245/21	271/9 271/18	327/26 301/31	•	•	•	•	•	321/40 336/55	289/26 289/28	263/29 264/30	249/40 256/42	247/55 256/46	•
•	200/20 170/22	174/14 177/19	254/19 203/22	242/14 220/16	3/23 343/5	347/40 327/23	358/46 15/41	8/47 12/46	348/50 4/62	329/36 349/37	271/37 262/39	259/43 252/45	250/52 248/56	246/62 248/65	•
•	152/18 141/24	163/15 220/23	320/26 242/42	309/39 256/69	38/26 161/5	14/35 348/10	20/42 41/39	13/39 34/41	348/41 12/53	321/31 343/27	265/39 251/37	258/54 246/52	251/64 244/66	247/72 243/74	•
•	119/17 180/7	102/13 246/35	78/16 248/49	29/13 258/71	21/17 263/81	15/21 266/76	13/27 279/71	357/28 32/28	337/34 7/41	304/30 313/23	258/37 246/36	254/57 243/59	250/72 241/75	249/83 244/85	•
•	184/9 79/3	•	188/9 219/12	341/10 250/28	323/14 262/26	319/17 277/21	331/25 341/24	319/27 215/4	298/29 297/18	283/30 282/28	257/42 264/42	252/63 263/61	248/73 264/70	249/83 269/81	•
•	•	•	•	•	273/27 259/35	269/28 269/24	290/29 314/24	269/44 309/35	268/56 290/42	280/36 294/42	254/51 256/53	252/59 250/62	252/62 246/65	252/64 245/70	•
•	•	•	•	•	•	•	263/48 263/44	260/44 264/47	262/57 264/74	261/53 265/82	•	254/53 260/47	251/57 256/58	251/53 250/56	•
						•	•	•	248/48 263/27	•	•	•	•	•	•
								•							

Plotting model:

Idd/Ivv Ddd/Dvv

	Average Error	
Verifying Date	EIdd/EIvv	EDdd/EDvv
2 January 12GCT	13.2/5.9	15.7/7.7
3 January 00GCT	20.1/7.6	23.7/9.1
3 January 12GCT	29.8/10.6	33.1/11.8
4 January 00GCT	33.5/7.4	28.5/12.5

Table VIa: Idd/Ivv: Interpolated kinematic 12 hour forecast verifying 4 January 1961, 00 GCT, using mean values at grid points between original unsmoothed input data at t=0 and direct kinematic 24 hour forecast smoothed by scanning for maxima and minima. Ddd/Dvv: Direct kinematic 12 hour forecast verifying 4 January 1961, 00 GCT; no smoothing on input data, smoothing on forecast.

	.														233/46 232/26
.	212/28 205/29	235/30 232/29	267/33 261/32	.	.	.	.	.	.	320/38 333/43	284/37 300/29	260/29 274/44	243/33 262/26	236/40 252/28	.
203/26 190/23	207/28 217/29	230/23 234/26	264/21 251/28	303/23 273/31	334/36 297/37	.	.	.	344/44 351/50	323/35 333/39	288/28 290/28	264/33 266/34	249/40 256/42	243/47 258/55	.
181/21 197/21	182/23 208/27	179/17 170/20	256/16 247/44	277/14 260/63	15/22 283/11	7/37 337/19	0/44 14/36	356/42 13/44	342/50 2/58	319/37 343/35	275/38 271/32	258/44 251/43	252/54 250/55	247/64 248/65	.
151/18 155/17	153/19 186/19	124/16 189/18	96/11 198/19	286/8 225/19	1/16 225/4	354/29 13/11	355/33 38/34	11/38 31/40	347/42 10/50	316/31 336/26	271/35 258/32	257/52 246/52	249/63 243/68	249/72 245/74	.
.	171/7 190/8	122/9 242/30	78/8 251/48	35/7 258/72	14/13 219/11	7/20 88/4	4/26 45/20	356/26 32/27	334/34 4/39	304/28 314/21	261/36 250/37	252/53 244/59	248/66 242/73	247/76 244/83	.
.	263/20 246/10	255/14 213/15	249/11 207/20	261/15 232/34	272/14 236/29	281/17 242/22	304/19 296/10	322/19 317/13	299/26 303/23	276/32 274/33	258/45 254/47	254/59 251/60	252/70 250/68	252/76 251/72	.
.	.	.	267/32 268/40	269/29 254/41	274/30 255/39	273/33 255/35	284/32 271/23	286/34 273/23	276/37 273/32	268/44 267/46	255/51 254/53	250/58 251/59	248/65 251/64	247/67 253/66	.
.	.	.	.	.	269/44 263/49	269/47 254/51	270/47 250/44	268/48 292/37	265/49 281/46	262/51 274/53	253/56 259/57	252/55 258/57	250/56 255/63	247/55 252/66	.
						.	264/59 280/58	257/57 272/48	256/56 270/46	255/57 265/52	253/51 263/60	253/53 262/51	255/46 263/43	252/40 258/41	.
								.							

Plotting model:

Idd/Ivv Ddd/Dvv

	Average Error	
Verifying Date	EIdd/EIvv	EDdd/EDvv
2 January 12GCT	13.1/4.3	17.5/5.3
3 January 00GCT	19.4/8.3	26.3/8.1
3 January 12GCT	27.6/12.1	27.3/11.9
4 January 00GCT	25.3/5.3	23.5/8.9

Table VIb: Idd/Ivv: Interpolated kinematic 12 hour forecast verifying 4 January 1961, 00 GCT, using mean values at grid points between original smoothed input data at t=0 and direct kinematic 24 hour forecast smoothed by scanning. Ddd/Dvv: Direct kinematic 12 hour forecast verifying 4 January 1961, 00 GCT; smoothing on input data and forecast.

which did not correspond to reality and which consequently resulted in high forecasting errors.

This was remedied by weighing original station values of $\bar{h}$ and Δh three times heavier than grid point data in the second run of the program which was responsible for this undesired amount of smoothing. The results, thus obtained, were quite satisfactory.

Slightly different kinematic forecasting procedures have been chosen for extrapolations of h and Δh than have been described in the foregoing for the wind-velocity components of the LMW. In accordance with a mean climatological rate of eastward displacement of jet-stream systems (Namias 1947), objectively analyzed grid-point values of $\bar{h}$ and Δh were moved to the right by 1½ grid distances in order to arrive at a 12 hour forecast of the $\bar{h}$ and Δh fields. In practice this was done by computing the average values between two horizontally adjacent grid points and then assigning these values to the next grid point to the right. With this method a significant improvement over persistence could be achieved in most of the forecasts of a 25-day sample described in the following chapter.

A data sample of forecasts is presented in Table VII. Programs are listed in Appendix 7.

(6) 25 Days of Objective Forecasting, January 1961

Figs. 9a to 9e show objective analyses of the LMW wind speeds and directions at 5-day intervals during the period January 1 to 25, 1961, for which the forecasting experiment described below has been conducted. Analyses have been obtained by using grid data of first scan equivalent to station data during a second program run. As may be seen from these analyses, the upper flow pattern showed considerable variability between zonal and meridional conditions of flow, thus giving a good indication of how the analysis and forecasting techniques described in this report will hold up under a variety of weather conditions at jet-stream level.

A time section of mean 24-hour forecasting errors in wind speed during this 25-day period, averaged over the grid of Fig. 4, is shown in Fig. 10. Errors of the kinematic extrapolation forecasts (solid lines) exceed the ones made by a persistence "forecasts" by about 3 mps on the average. As will be shown later, most of these errors seem to concentrate in particular regions, such as the Pacific Northwest of the United States where - as has been pointed out earlier - the scanning of wind maxima and minima in order to reduce the truncation errors was ineffective. It is felt that forecasting errors in these regions could be reduced drastically by extending the objective analysis across the northern border of the United States into Canada.

Mean errors of wind direction extrapolation presented in Fig. 11 show essentially the same deficiencies as the forecasts of wind speeds. The mean error of kinematic extrapolation is approximately 6 degrees larger than the mean error of persistence. Consequently the root mean squared errors of the vector wind, shown in Fig. 12 turn out to be appreciable. Again, the kinematic extrapolation techniques seem to be inferior to persistence by about 4 mps on the average.

	.														6983 19941
.	.	3468 11233	3630 10643	.	.	.	.	.	.	.	4171 14629	4994 17660	5863 18267	6660 18552	6870 17278
2994 11498	3287 12248	3815 12691	4030 11761	3682 10560	2889 8890	. .	.	.	.	4440 11846	5308 16557	5994 18539	6169 16800	6477 15900	6504 14949
3274 12434	4129 14173	4833 15221	5201 15204	5128 14767	4769 13852	4425 13097	4261 12600	4254 11801	4362 11642	5019 13595	6280 17649	6854 19004	6767 16858	6535 14343	6158 11813
3252 12769	4012 14012	5045 15316	5971 16616	6018 16661	5740 16307	5614 16254	5054 14717	4570 12980	4511 12527	5133 14387	6198 17589	6279 17123	5789 14844	5591 13493	5628 12175
4807 15695	5221 16365	6175 17694	6756 18703	6840 19152	6937 19669	6999 19999	6332 18203	5387 15640	5246 15236	5483 15276	5928 15717	6042 15393	5602 13407	5004 11956	4570 11450
.	4575 15323	5338 16126	5920 17039	6092 17126	6114 17522	6530 18913	6440 18532	5839 16884	5881 16904	5850 15429	5788 13578	5594 13673	4918 12445	4333 11770	3525 12102
.	4197 15038	5262 16033	5998 16879	6211 17554	5659 16683	5661 16901	6571 18228	6333 17121	5565 15700	5508 14611	5941 14004	6085 13994	5438 12740	4677 12022	4146 11901
.	.	4661 15939	5670 17365	5580 16720	4789 15005	4652 14948	5183 16058	5523 16305	4532 15913	4137 13800	5069 12106	5752 12513	5925 13120	5348 13886	5100 13200
.	.	.	.	5370 16371	3980 13202	3686 12638	4239 13634	4449 13552	4283 13141	4414 13068	5055 12736	5793 12688	5965 13682	5774 15235	5204 14427
.	.	.	.	.	.	3299 10435	3536 11676	3916 12451	3567 12432	4100 12377	5566 12344	.	.	6430 14772	6362 16189
						.	.	3967 12188	4286 12548	5422 12601	.	.	.	5798 11317	6006 13638
								.							

Plotting model:

$\frac{\Delta h}{\bar{h}}$

Table VIIa: Direct 12 hour forecasts of thickness (Δ h) and height ($\bar{h}$) of LMW, verifying at 4 January 1961, 00 GCT; smoothing on input data, no smoothing on forecasts.

	·														·
·	·	-783 -1625	·	·	·	·	·	·	·	·	-434 396	-946 -2731	-710 317	-585 -1338	·
1889 245	883 -467	-568 -1882	-1629 -1638	-1296 -32	·	·	·	·	·	542 3438	-1282 -2546	-2171 -6519	-1590 -2888	-853 -2830	·
2555 1887	594 35	-1424 -3217	-2538 -3871	-2577 -3927	-2067 -3238	-594 -2667	520 -2688	1290 73	1309 1531	406 1909	-1987 -4086	-2935 -7535	-2438 -5546	-1404 -3928	·
2949 2475	1575 2873	-514 237	-2183 -2355	-2770 -3619	-1680 -2619	-495 -1734	307 -1696	1624 1655	1604 2823	693 1643	-1008 -2323	-1939 -4207	-1790 -3583	-1041 -3346	·
1746 405	335 1979	-2346 -2366	-2614 -3243	-2965 -4255	-2636 -5057	-1228 -3594	-358 -3328	969 930	1635 2795	1374 2345	582 3043	-189 1742	-1047 -240	-880 -866	·
·	-579 681	-1277 -150	-1587 -920	-2369 -2232	-2194 -2299	-810 -443	-722 -1822	-144 -701	281 -1785	553 761	2951 10907	2175 8793	1148 5750	145 2510	·
·	1373 2472	-408 1065	-522 873	-2445 -2041	-2004 -1067	-1034 -585	-1612 -2976	-826 -2357	239 -2255	-1218 -2479	-1349 130	-2548 -1449	-2007 -2225	-2253 -5223	·
·	·	654 51	-215 -1486	-995 -2666	-479 -1181	-687 -973	-1321 -2499	-1915 -3654	140 -3652	-212 -2935	-1196 -632	-1159 15	-213 300	-3453 -10348	·
·	·	·	·	709 -3954	1336 -173	1255 599	736 -1047	181 -1129	70 -943	-397 -1944	-1339 -1887	-1739 -2997	-1807 -3885	-782 -835	·
·	·	·	·	·	·	2048 2607	1266 1402	417 478	704 603	880 1375	-1129 682	·	·	-692 1117	·
						·	·	-42 1683	·	·	·	·	·	-663 5028	·
								·							

Plotting model:

E Δ h
Eh

	Average Error	
Verifying Date	E Δ h	$\overline{Eh}$
1 January 12GCT	1250.1	2797.6
2 January 00GCT	766.9	2222.4
2 January 12GCT	853.2	2230.1
3 January 00GCT	782.6	1909.8
3 January 12GCT	1046.1	2048.1
4 January 00GCT	1251.9	2315.0
4 January 12GCT	871.9	2424.8

Table VIIb: Differences between actual and forecast thicknesses (E Δ h) and heights (Eh) of LMW, verifying at 4 January 1961, 00 GCT; smoothing on input data, no smoothing on forecasts.

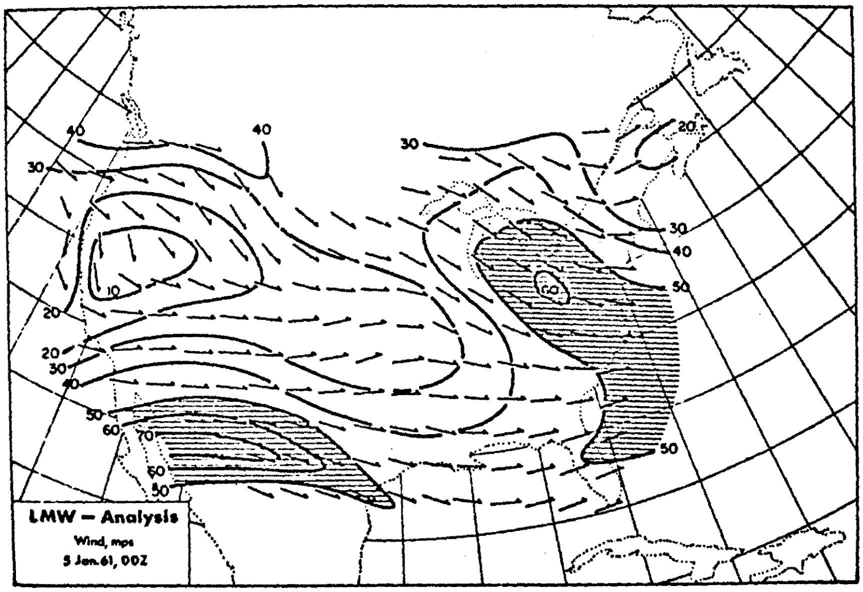
	.														.
744 -1331	-364 -811	-842 -534	.	.	.	.	.	.	635 1417	-296 -3633	-1599 -3131	-2343 -3448	-1776 -144	-737 1385	.
1268 -1185	155 -672	-798 -261	-919 73	-73 2797	.	.	.	8 -224	69 -2081	-969 -3818	-2012 -3965	-2478 -3604	-2074 -2264	-731 -652	.
1203 -908	-318 -1003	-1952 -3193	-2233 -3005	-2092 -2526	-1506 -2215	-484 -1941	588 -1320	1015 -178	162 -1963	-1626 -4657	-2363 -4284	-2959 -4401	-1863 -1504	-994 -395	.
1773 731	-75 766	-1749 -1558	-1968 -1949	-2477 -3362	-1443 -2416	514 1190	825 390	1708 2213	337 -1002	-791 -2795	-751 -154	-1297 -1353	-1546 -1456	-1161 -1486	.
910 -848	-1150 -97	-2976 -3637	-2734 -3880	-3124 -5102	-2698 -5387	106 -3	865 3	972 969	1300 3081	582 1137	701 4458	459 4625	-59 1766	-403 -409	.
603 -280	-1633 -588	-2150 -1510	-1640 -648	-2533 -3383	-2885 -4326	-355 955	115 457	-464 -1373	620 1817	370 2335	3584 10995	3089 11066	2080 6056	1414 2216	.
705 -1296	-166 1227	-1405 -376	-687 119	-1390 -220	-2511 -2454	-2349 -2071	-731 -603	66 -782	230 -232	-2018 -2199	-1270 476	-1478 722	-908 -1706	-1530 -4783	.
1991 123	239 -96	-668 -1715	278 144	183 -221	-593 -1797	-1498 -2520	-1721 -2557	126 -3060	-119 372	-1422 -1458	-2284 -1230	-1100 -1007	709 -817	-3302 -8625	.
.	.	1202 -450	2318 -30	2630 438	1394 -268	385 -735	633 -546	408 -727	-252 -788	-1489 -1362	-2364 -2042	-1796 -4783	-1540 -6200	281 1543	.
.	.	.	.	3865 2186	3125 1565	1592 661	725 557	1277 588	-871 623	-1010 1475	.	-1780 -1378	-1469 -2040	-440 -877	.
						1170 1787	245 1434	-773 1244	.	.	.	-1943 3755	-2238 623	-1063 1091	.
								.							

Plotting model:

E Δ h $\overline{Eh}$

	Average Error	
Verifying Date	E Δ h	$\overline{Eh}$
1 January 12GCT	1435.0	2938.0
2 January 00GCT	894.8	2353.3
2 January 12GCT	878.5	2263.8
3 January 00GCT	876.2	2484.8
3 January 12GCT	966.6	2273.2
4 January 00GCT	1265.9	1885.4
4 January 12GCT	1063.5	2809.5

Table VIIc: Differences between actual thicknesses (E Δ h) and heights ($\overline{Eh}$) of LMW and forecast made by "persistence", verifying at 4 January, 1961, 00 GCT; smoothing on input data, no smoothing on forecasts.



a.

b.

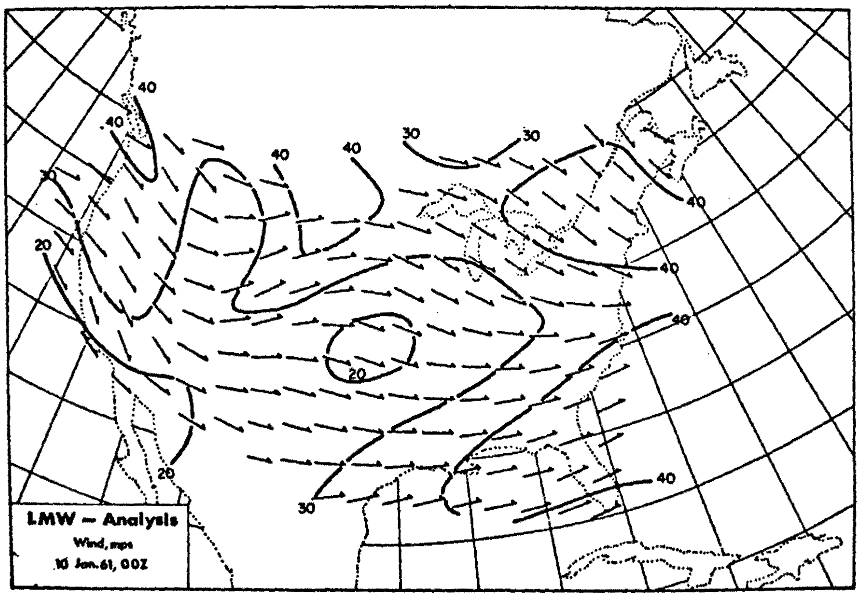
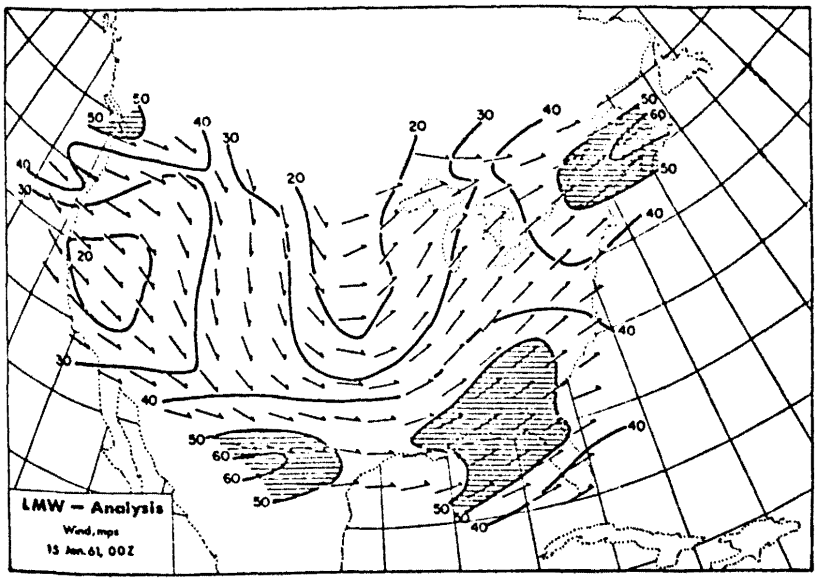
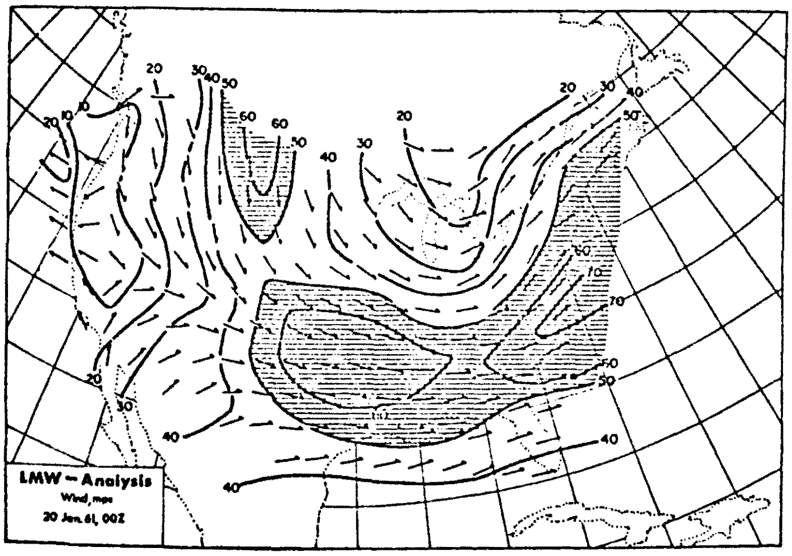


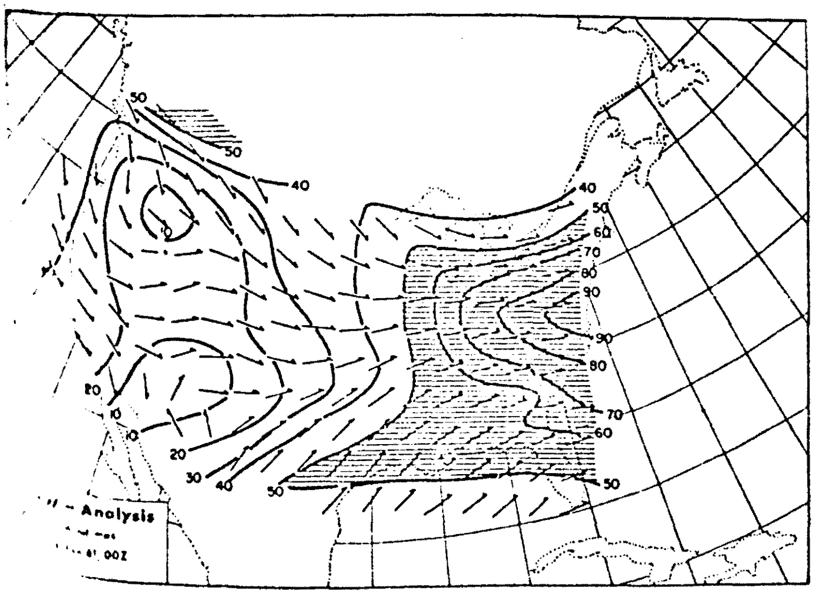
Fig. 9: Objective LMW analyses of wind speeds (mps, areas with speeds > 50-mps are shaded) and wind directions (indicated by arrows at grid points) for dates as shown.


LMW — Analysis
Wind, mps
15 Jan. 61, 00Z

c.


LMW — Analysis
Wind, mps
20 Jan. 61, 00Z

d.


— Analysis
61, 00Z

e.

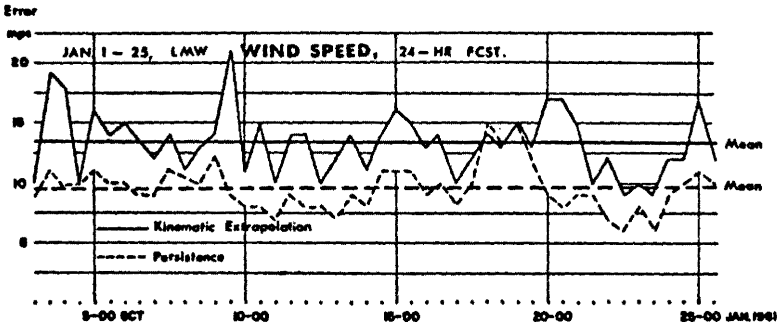


Fig. 10: Time section of mean forecasting errors of wind speeds (mps) made by kinematic extrapolation and by persistence, averaged over grid points shown in Fig. 4.

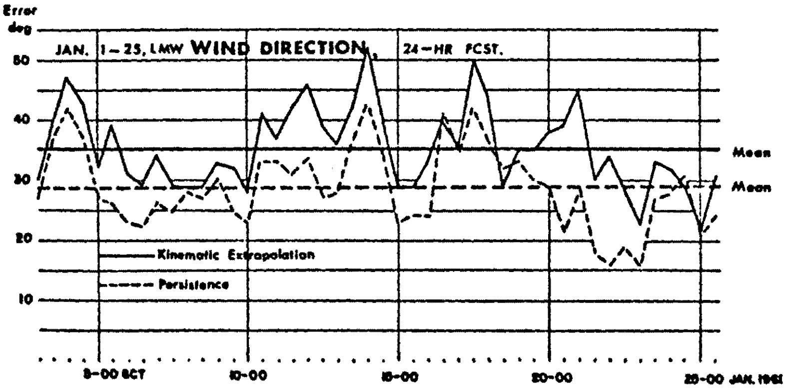


Fig. 11: Time section of mean forecasting errors of wind direction (degrees) made by kinematic extrapolation and by persistence, averaged over grid points shown in Fig. 4.

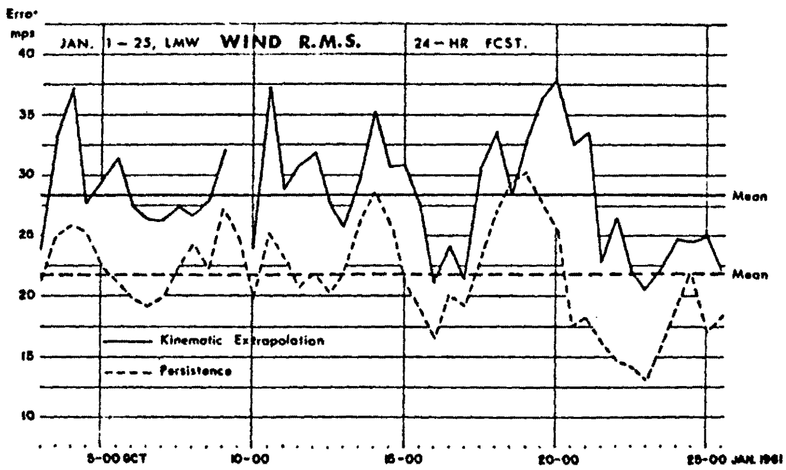


Fig. 12: Time section of RMS error of wind forecasts (mps) made by kinematic extrapolation and by persistence, averaged over grid points shown in Fig. 4.

Lack of time did not permit the testing of different analysis techniques. A tie-up with the geostrophic wind field at some upper-level constant pressure surface might conceivably improve the quality of objective analyses as well as of forecasts, the latter beyond the skill-level set by persistence.

The height of the LMW is forecast better by kinematic extrapolation than by persistence, even with the analysis techniques utilized in this study (Fig. 13). On the average, the improvement is about 125 m when using the kinematic technique. Similar conditions hold for predictions of the thickness of the LMW (Fig. 14) where the kinematic extrapolation errors are about 100 m less in the mean than errors from persistence forecasts. Apparently vertical wind shear patterns are shifting more rapidly with time than LMW wind speed and mean wind direction themselves. The lesser amount of smoothing applied to the height and thickness analyses by weighing actual station data with a factor of three during the second run of the analysis program, as compared with grid-point data obtained during the first run also had a favorable effect upon the quality of the forecasts.

For more detailed consideration of the quality of analyses and forecasts, the predictions verifying at 4 and 23 January 1961, 00 GCT, are presented in the following. As may be seen from Fig. 12, the root-mean squared errors of the forecast vector winds attained maximum values on 4 January 00 GCT, and minimum values on 23 January, 00 GCT.

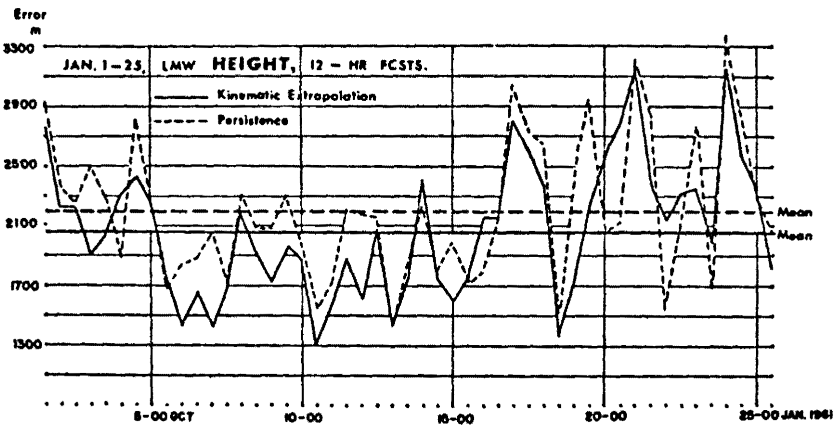


Fig. 13: Time section of mean forecasting errors of LMW heights (m), made by kinematic extrapolation and by persistence, averaged over grid points shown in Fig. 4.

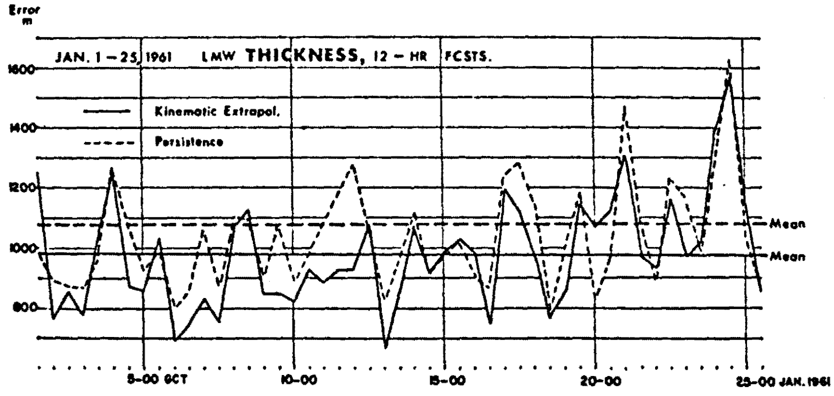


Fig. 14: Time section of mean forecasting error of LMW thicknesses (m), made by kinematic extrapolation and by persistence, averaged over grid points shown in Fig. 4.

The actual objective analyses of the LMW parameters of 4 January, 1961, 00 GCT, to which the forecasts will have to be compared, are shown in Figs. 5, 6 and 7. The slightly excessive amount of smoothing which becomes evident by comparing station data with the analyses of grid point values presented by the iso-lines may be, at least in part, responsible for the inferiority of kinematic extrapolation to persistence.

The 24-hour forecasts of LMW speeds and directions, and 12-hour forecasts of LMW heights and thicknesses verifying on 4 January, 1961, 00 GCT are shown in Figs. 15, 16, and 17. For comparison, the jet axes from the objective analysis of Fig. 5 have been entered as heavy dashed lines with arrows. Forecasts of wind speeds and directions were made by scanning the input data twice, using grid point data from the first run equivalent to station data during the second run. The forecast was scanned again in order to reduce main maxima and minima of wind speeds to their original size. The excessive wind speeds of more than 100 mps forecast over the Pacific Northwest are obviously caused by truncation errors, as pointed out earlier, because the scanning technique failed in this region. The blocking high over Oregon and Washington did not materialize either.

The general pattern of heights and thicknesses of the LMW is brought out rather well in the forecasts, although the sharp gradients appearing in the actual analyses (Figs. 6 and 7) are damped considerably in the forecasts.

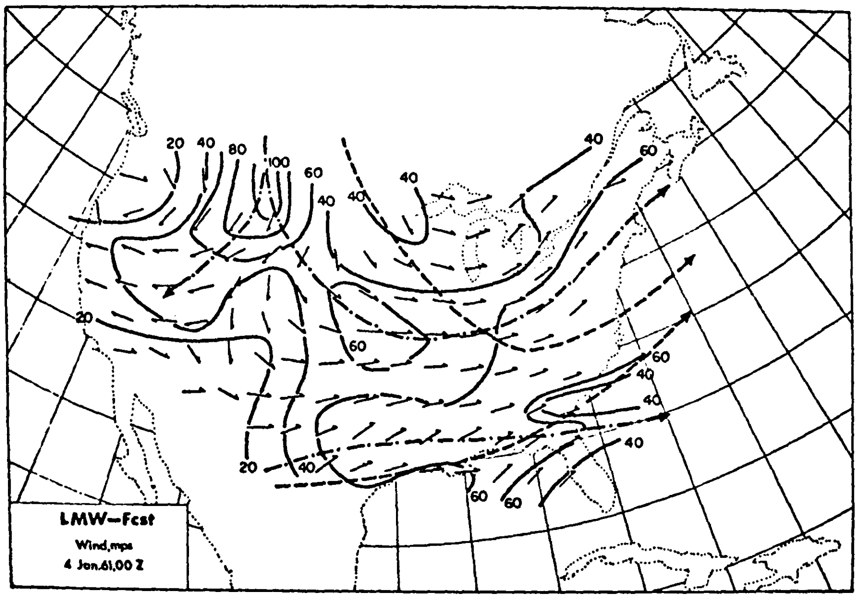


Fig. 15: 24-hour forecast of LMW speeds (mps) and directions (arrows at grid points), verifying 4 January 1961, 00 GCT. Dashed-dotted lines: forecast jet axes; dashed lines: jet axes as in Fig. 5.

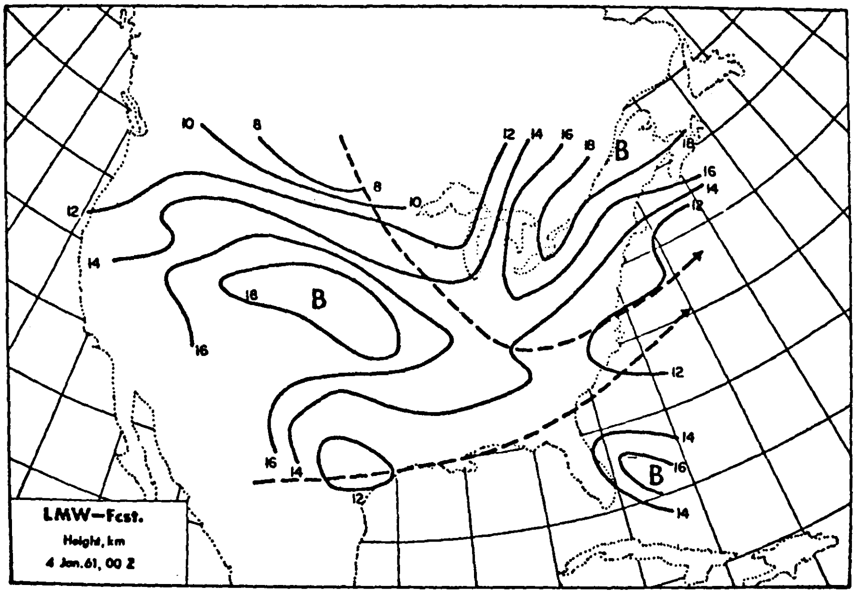


Fig. 16: 12-hour forecast of LMW heights (km), verifying 4 January 1961, 00 GCT. B = barotropic regions. Dashed lines: jet axes of Fig. 5.

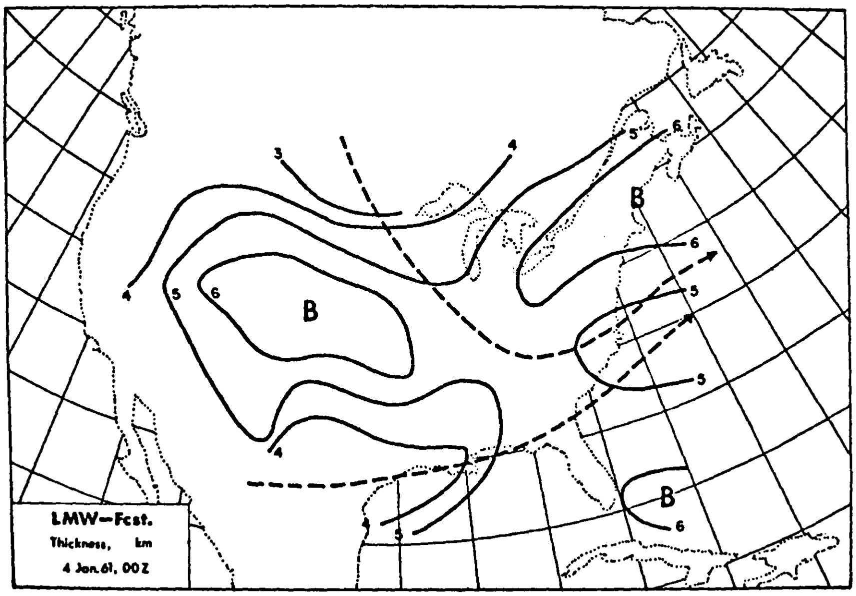


Fig. 17: 12-hour forecast of LMW thicknesses (km), verifying 4 January 1961, 00 GCT. B = barotropic regions. Dashed lines: jet axes of Fig. 5.

Figs. 18 and 19 show the errors of kinematically extrapolated wind speeds (mps) and wind directions (deg) of the LMW, and the errors made by persistence. Both evaluations again, are based upon objective machine analyses. Extrapolation as well as persistence show substantial forecasting errors over the Northwestern United States. Over most of the Central and Eastern United States the errors are within tolerable limits.

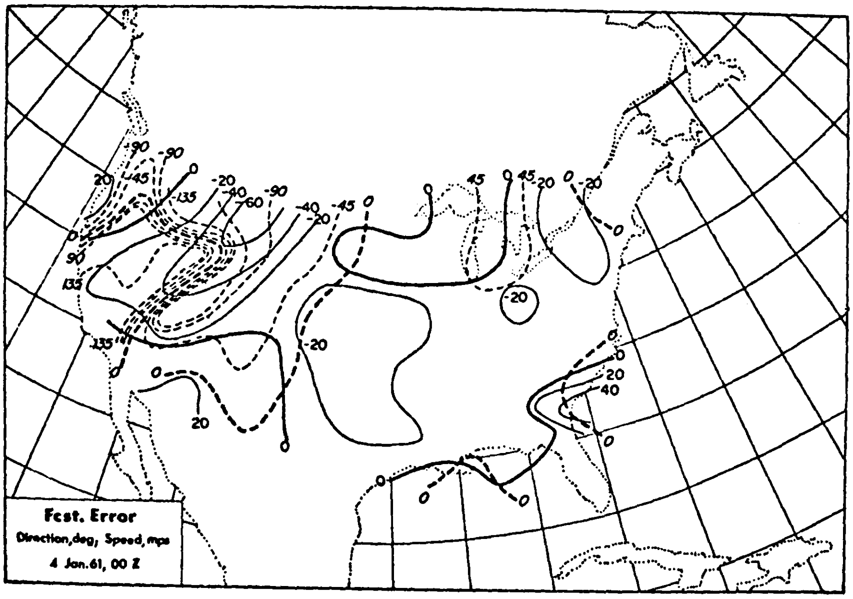


Fig. 18: Errors of 24-hour forecasts verifying 4 January 1961, 00 GCT of LMW speeds (mps, solid lines, vertical numbers) and directions (degrees, dashed lines, slant numbers). Errors were computed as differences between Figs. 15 and 5.

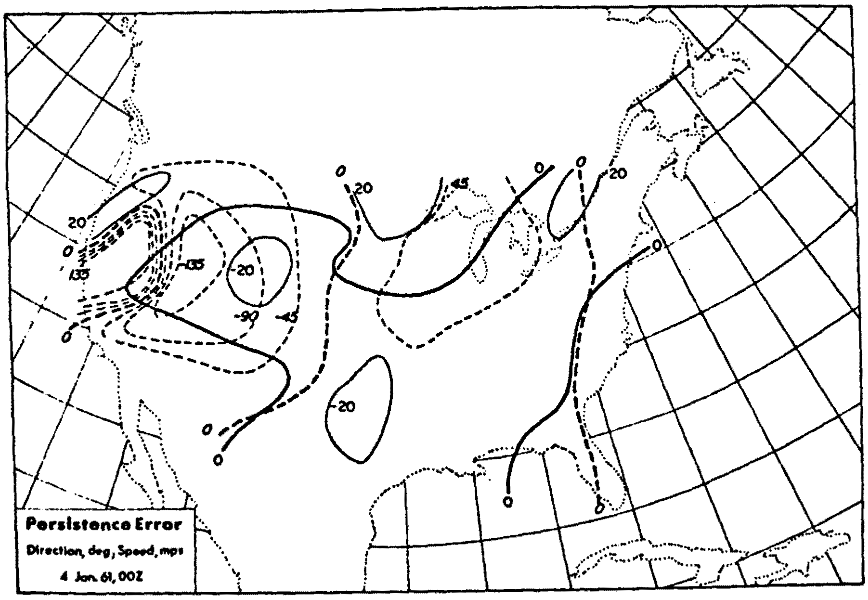


Fig. 19: Errors made by 24-hour persistence "forecast", verifying 4 January 1961, 00 GCT, of LMW speeds and directions. Same notation as in Fig. 18.

In Figs. 20 and 21, the differences in magnitude of extrapolation and persistence forecasts are shown for wind speeds and for wind directions of the LMW. Kinematic extrapolation produced predictions of better quality than persistence within the shaded regions. While over the area of the whole United States on the average wind speeds forecast with the present techniques of analysis and extrapolation are not able to match persistence, the areas with some skill in the direction forecasts exceed the ones with no skill.

Again it should be emphasized that improvements are to be expected with more sophisticated objective analysis techniques.

The case of 23 January 1961, 00 GCT with minimum forecasting errors is discussed in the following.

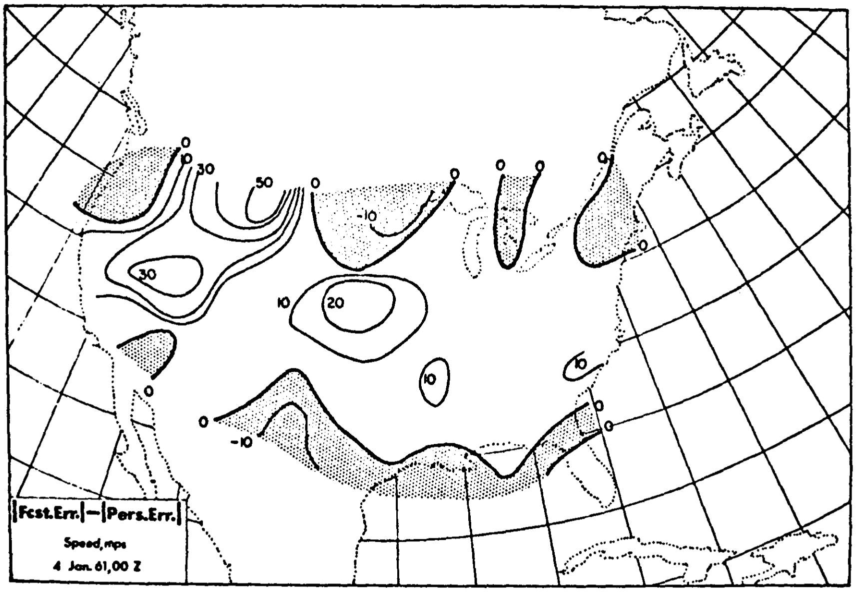


Fig. 20: Differences in magnitude between 24-hour forecasting error and persistence error of LMW speeds (mps), verifying 4 January 1961, 00 GCT. Over the shaded regions forecasting errors are less than persistence errors.

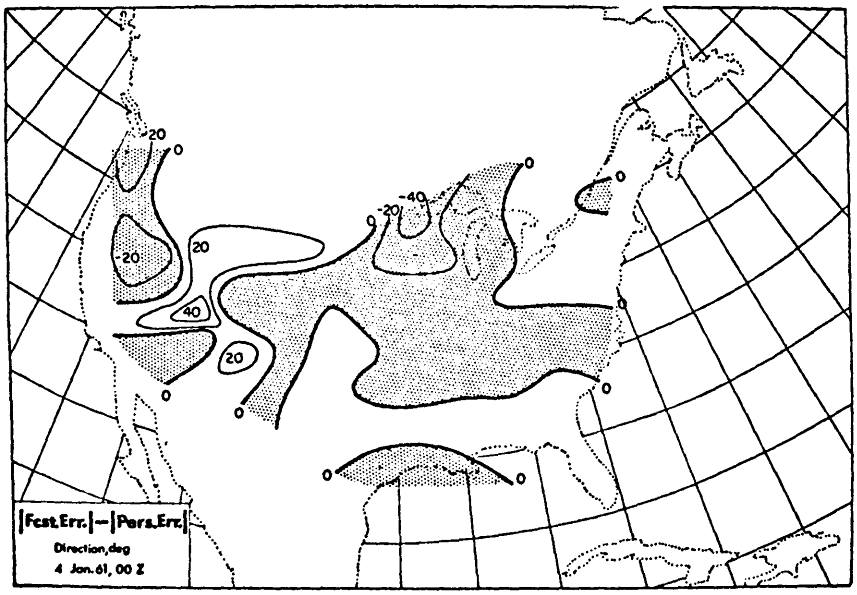


Fig. 21: Differences in magnitude between 24-hour forecasting error and persistence error, of LMW directions (degrees), verifying 4 January 1961, 00 GCT. Over the shaded regions forecasting errors are less than persistence errors.

Analyses of LMW parameters at verifying time are presented in Fig. 22, 23 and 24. In comparison with the case of 4 January 1961, they show more zonal flow conditions over the eastern United States, and a sharper ridge over the Pacific Northwest.

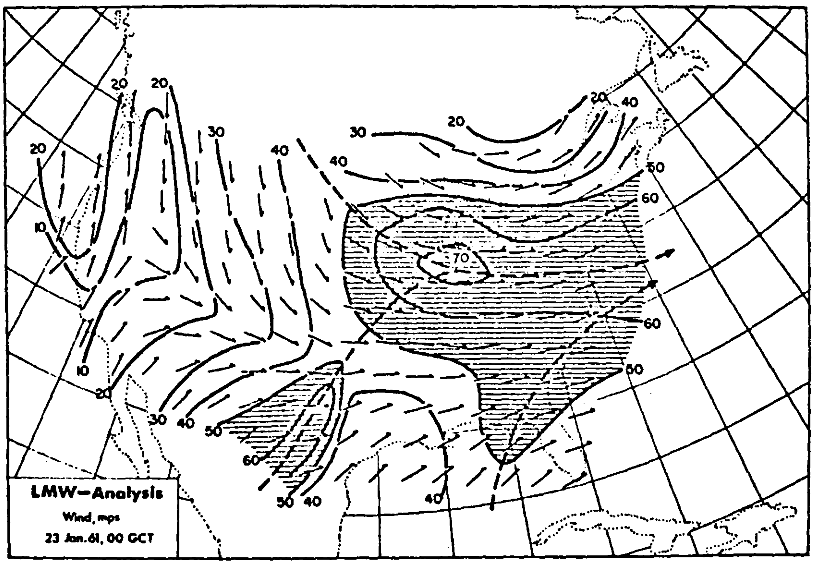


Fig. 22: Objective analysis, 23 January 1961, 00 GCT, of LMW speeds (mps, areas with speeds > 50 mps are shaded) and directions (thin arrows at grid points), obtained from grid point data. The heavy dashed lines with arrows indicate the position of jet axes.

The 24-hour forecasts of winds and 12-hour forecasts of heights and thicknesses of the LMW shown in Figs. 25, 26, and 27, bring out the general features of the upper flow pattern. The southwesterly jet-stream branch over Texas is not shown in the correct location, however, nor is the jet axis of the main jet stream over the eastern U.S. In view of the broadness of this jet, the errors made in positioning the axis are of not too serious consequence, as may be seen from the error analysis of Fig. 28.

Both, actual forecast and persistence (Fig. 29) predict the wind directions poorly over the western United States within the region of anticyclonic, but light, winds. The failure to forecast the southwesterly jet stream over Texas causes large errors in speed over this area, shown in Fig. 28. Problems of poor data coverage along the boundaries of the grid aggravated the deficiencies in the forecast. Different analysis techniques may remedy some of the shortcomings.

The forecasts of height and thickness of the LMW (Figs. 26 and 27) showed some gaps over the eastern United States. Several soundings over this region were not able to penetrate the rather strong jet stream far enough to permit computation of these two LMW parameters.

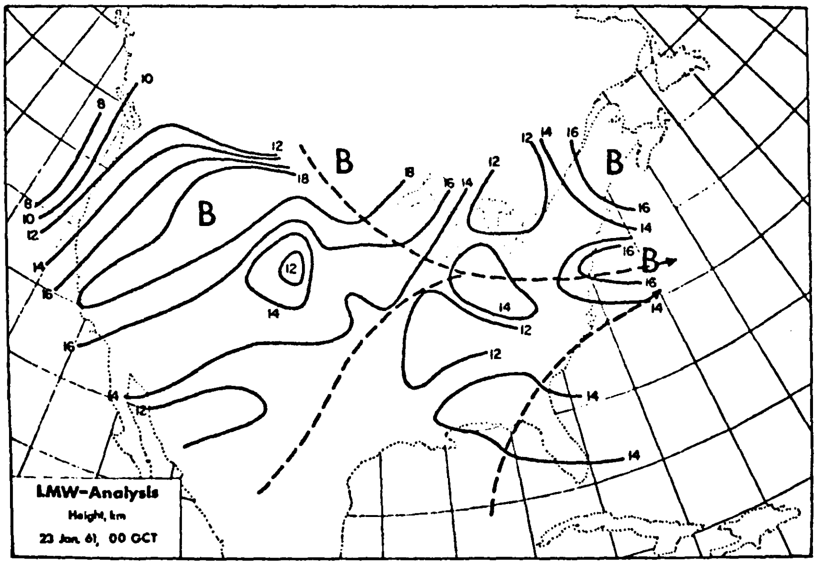


Fig. 23: Objective analysis, 23 January 1961, 00 GCT, of LMW heights (km). B = barotropic regions. Jet axes as in Fig. 22.

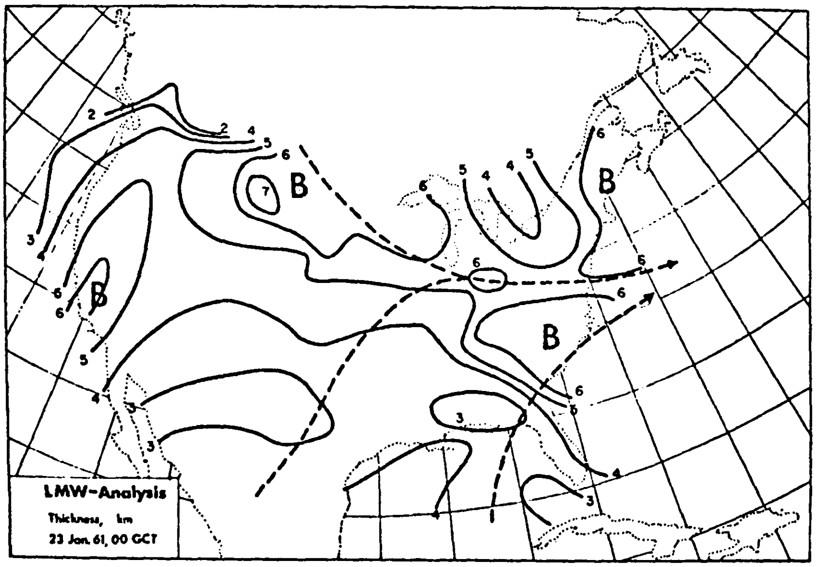


Fig. 24: Objective analysis, 23 January 1961, 00 GCT, of LMW thicknesses (km). B = barotropic regions. Jet axes as in Fig. 22.

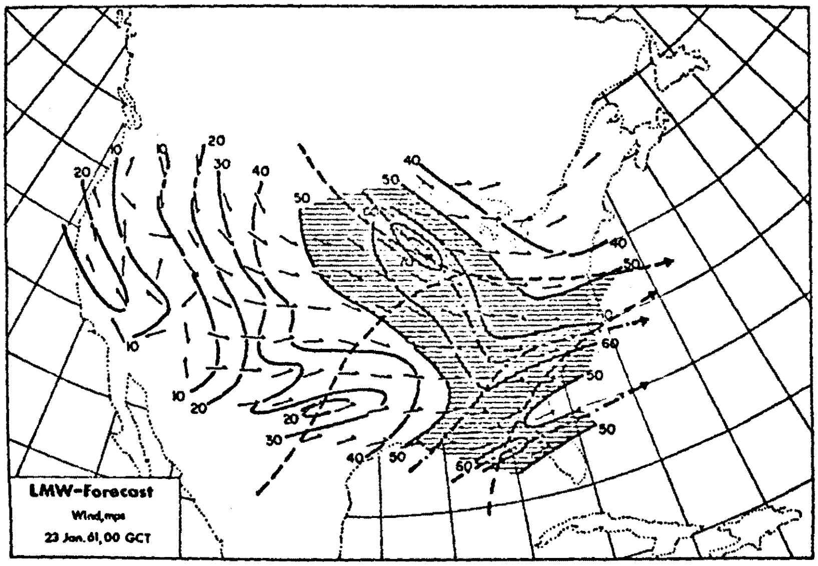


Fig. 25: 24-hour forecast of LMW speeds (mps, areas with speeds > 50 mps are shaded) and directions (arrows at grid points), verifying 23 January 1961, 00 GCT. Dashed-dotted lines: forecast jet axes; dashed lines: jet axes as in Fig. 22.

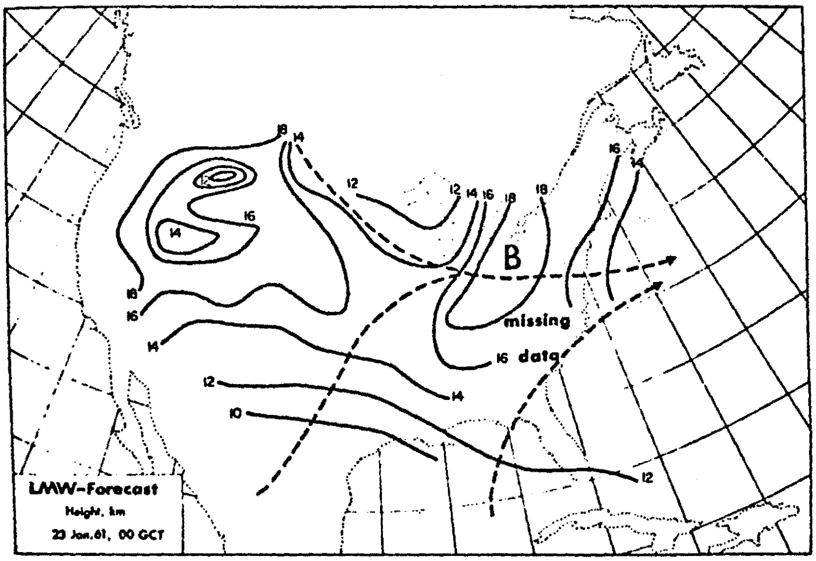


Fig. 26: 12-hour forecast of LMW heights (km), verifying 23 January 1961, 00 GCT. B = barotropic regions. Dashed lines: jet axes of Fig. 22.

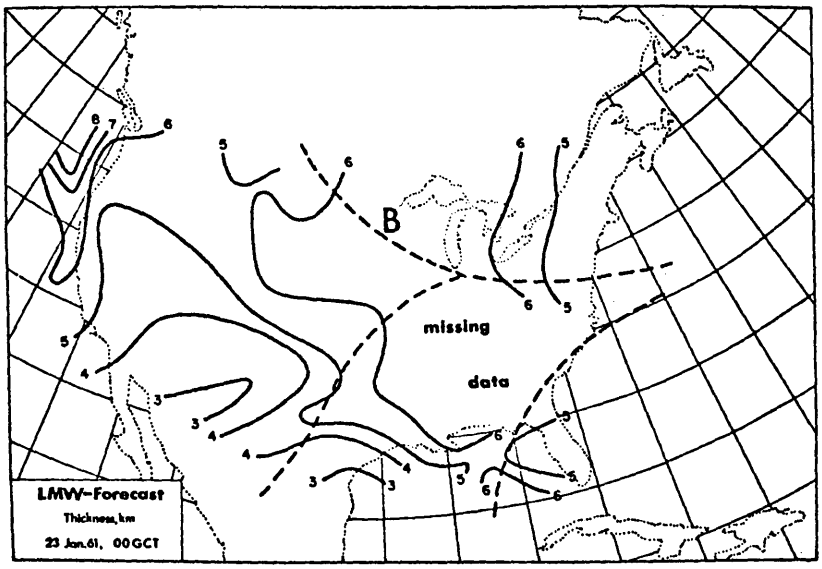


Fig. 27: 12-hour forecast of LMW thicknesses (km), verifying 23 January 1961, 00 GCT. B = barotropic regions. Dashed lines: jet axes of Fig. 22.

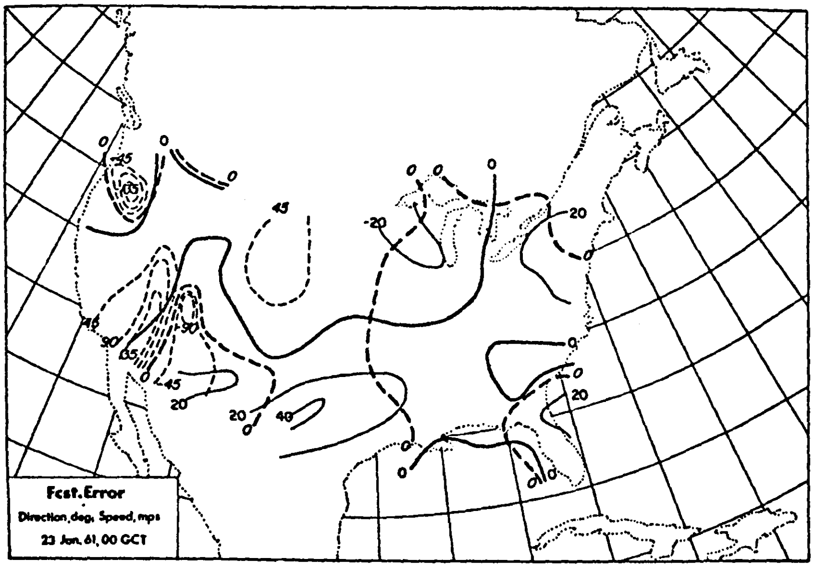


Fig. 28: Errors of 24-hour forecasts, verifying 23 January 1961, 00 GCT, of LMW speeds (mps, solid lines, vertical numbers) and directions (degrees, dashed lines, slant numbers). Errors were computed as differences between Figs. 25 and 22.

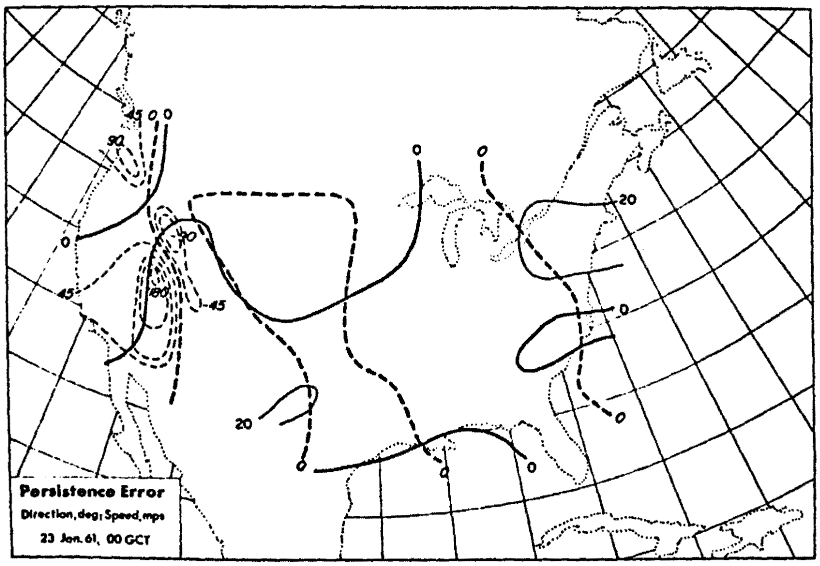


Fig. 29: Errors made by 24-hour persistence "forecast", verifying 23 January 1961, 00 GCT, of LMW speeds and directions. Same notation as in Fig. 28.

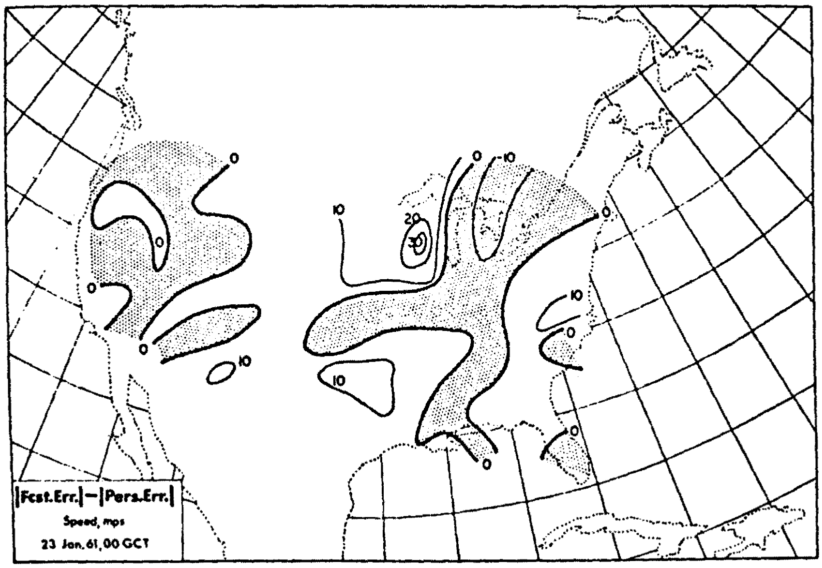


Fig. 30: Differences in magnitude between 24-hour forecasting error and persistence error of LMW speeds (mps), verifying 23 January 1961, 00 GCT. Over the shaded regions forecasting errors are less than persistence errors.

Figs. 30 and 31 give a comparison of errors made by the 24-hour kinematic forecast and by persistence. While the average performance of the forecast is better than was the case in the example of 4 January, the areas over which the forecasts show some skill seem to be only slightly larger for speeds, slightly smaller, however, for directions.

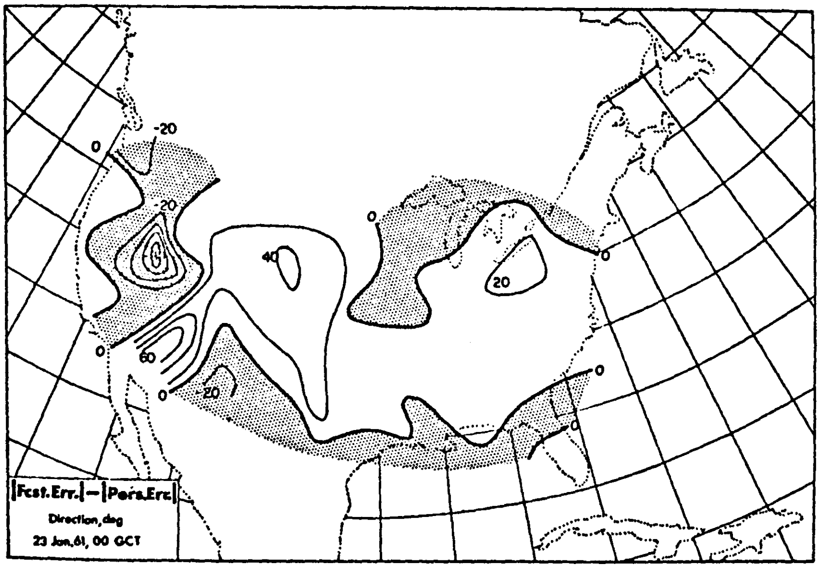


Fig. 31: Differences in magnitude between 24-hour forecasting error and persistence error, of LMW directions (degrees), verifying 23 January 1961, 00 GCT. Over the shaded regions forecasting errors are less than persistence errors.

V. Conclusions and Outlook for Further Research

The computer programs described in the foregoing sections, and listed in the appendices, constitute parts of a package encompassing all the necessary steps from data processing through analysis to forecasting. Using an IBM-7090 computer, the following average computer times were consumed during the various computation steps:

Error checking, harmonic analysis, and extraction of LMW parameters: 1 sec per sounding. (This average value includes soundings which were rejected from harmonic analysis because of their shortness).

Objective analysis of LMW speeds and directions, converting station to grid-point data, and treating grid data of first run equivalent to station data during second run: 45 seconds per map (continental United States).

Objective analyses of LMW heights and thicknesses: ca. 25 sec. per map time for both parameters, (continental United States).

24-hour forecasts of LMW speeds and directions, with scanning for maxima and minima in order to reduce truncation error: 6 seconds per map (continental United States).

12-hour forecasts of LMW heights and thicknesses: 12 seconds per map time for both parameters (continental United States).

While the main objectives of this research program were to devise and test objective and high-speed techniques for forecasting the upper wind field, it became increasingly apparent during the investigation, that considerable more effort will have to be devoted to improvements in objective analysis techniques, before kinematic extrapolation will yield the desired quality of forecasts.

Experiments will have to be run with successive approximation techniques, such as recommended by Bergthorrsson and Döös (1955) and by Cressman (1959).

The rawinsonde network over the United States seems to be sufficiently dense to allow a consistent representation of the upper flow pattern in terms of LMW parameters. A further step towards realizing the objectives of an Automatic Air Traffic Control System, of course, necessitates the recovery of wind speed and direction at any particular flight level from these LMW parameters. Computer programs for this phase have not yet been developed. They will, however, be easy to design, if certain simplifying assumptions can be made.

In first approximation we may assume that the harmonically smoothed wind profiles are symmetric about the mean height of the LMW, and that they may be represented by straight lines, at least within the thickness Δ h of the LMW (Reiter 1958). Improvements over these assumptions may be made statistically from actual data.

The wind at any given level within the range of Δ h may be computed as follows, under the assumptions stated above:

$$(V_{max} - 0.8\, V_{max}) : \frac{\Delta h}{2} = (V_{max} - V) : \left| z - \bar{h} \right| \qquad (3)$$

where V_{max} is the wind speed at flight level z, which may lie above or below the mean height $\bar{h}$ of the LMW. Equ. (3) yields

$$V = V_{max} - \frac{0.4}{\Delta h} \times V_{max} \times \left| z - \bar{h} \right| \qquad (4)$$

Extrapolation of vertical shears computed from Δh to layers outside the LMW should be attempted by using regression equations similar to the ones developed by Reiter (1958).

In forecasting outside the LMW, especially in the stratosphere near the upper limits of the specified air space (50,000 ft), one might be able to use persistence as a prediction tool, since stratospheric flow patterns are known to change but slowly. A persistence "forecast" at the 50,000 ft. level, combined with kinematic extrapolation of the LMW, might yield useful wind predictions for the total air space from 20,000 to 50,000 ft. For lack of time, the development and testing of computer programs of such nature had to be left to future research efforts.

It will be necessary to run extensive comparisons between winds at specific levels derived from LMW parameter analyses and forecasts, and winds analysed and predicted directly on such a specific level. A study of this nature should reveal the relative advantages and disadvantages of using vertically integrated parameters in describing the three-dimensional wind field, rather than a multi-layered model of the atmosphere.

Last, but not least, computer programs will have to be developed which will yield the mean wind speed and direction along any given flight leg and flight level from LMW grid-point data. Since this constitutes only a simple application of interpolation equations, no major difficulties should be expected in this task.

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Appendix 1: Layout of data cards, containing minute-by-minute wind reports

COLUMNS	ITEMS	REMARKS
1 - 5	Station No.	
6 - 7	Year	
8 - 9	Month	
10 - 11	Day	
12 - 13	Hour	Schedules time 00 or 12 plus or minus 1-1/2 hours. If more than 1-1/2 hours off scheduled time punch actual time.
14 - 16	Beginning Minute	Sfc is punched 000 minute (1st card for each flight). Cols. 14-16 will be punched in other cards indicating the first minute for which data is punched in Cols. 17-22.
17 - 64	Wind Direction and Wind Speed	Wind Direction 360° Wind direction and speed at consecutive 1 minute or 2 minute intervals for the entire flight. Winds reported in mps and tenths. Winds reported in knots will be punched to whole knots - rounding off tenths position if any. For wind speeds of 100 or more, 500 will be added to the wind direction. (Cols. 17-19, 23-25, etc.).
65 - 69	Altitude of Last Minute Punched in Card	Height of last minute punched in card, prefixing '0' where necessary, when entered at the same minute wind direction and speed is reported. If height is not entered on the same minute as wind direction and speed is reported, punch next lowest height prefixing '0' where necessary.
70	Minute Identifier	Punch 1 when card contains wind direction and speeds at 1 minute intervals. Punch 2 when card contains wind direction and wind speeds at 2 minute intervals.
71	Wind Speed Identifier	Wind speeds in mps - punch 0. Wind speeds in knots - punch 1.
72	Height Identifier	Punch X if height is reported for one minute earlier than for the last wind direction and speed punched in the card. Leave blank if the height is reported for the same minute as the wind direction and speed for the last minute punched in card.
73 - 79	Leave blank	
80	Last card of flight	Punch 1 for the last card of the flight. Leave blank on all other cards.

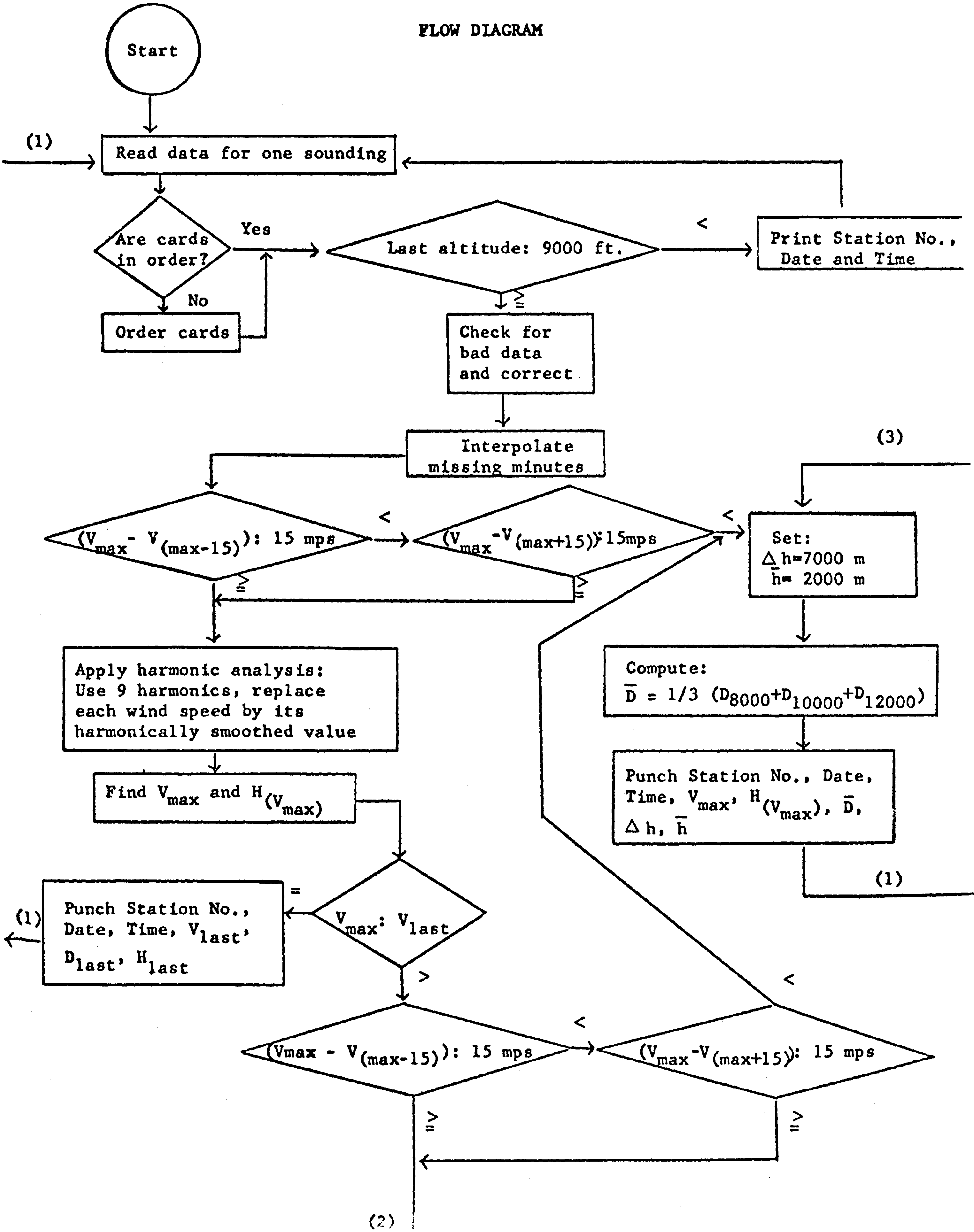
FOR MISSING MINUTES:

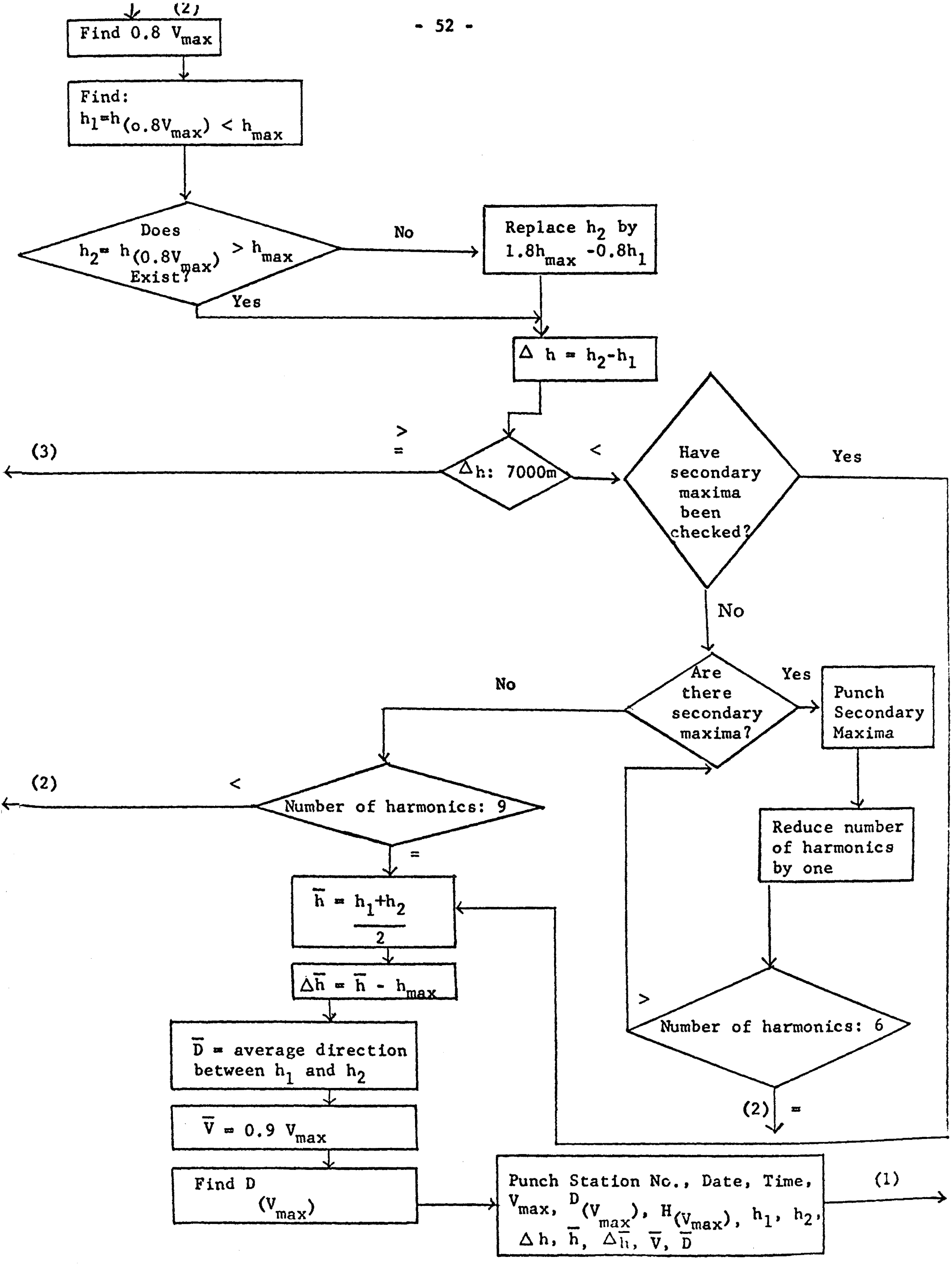
When minutes are missing between values punched on the same card, punch XXXXXX for missing data.
When minutes are missing and continue to be missing beyond card on which reported wind directions and speeds end, punch XXXXXX in columns for remainder of card through column 64. Punch height of wind direction and speed at last minute reported and begin the next card with the minute for which wind direction and speeds are reported again.

Appendix 2: Program for determining Layer of Maximum Wind (LMW) Parameters.

The program "LMW" checks the input data cards for order, checks for bad data, uses the harmonic analysis to smooth the wind profile and then computes and punches LMW parameters.

FLOW DIAGRAM




(2)
Find 0.8 Vmax
Find:
h1=h(o.8Vmax) < hmax
Does
h2= h(0.8Vmax) > hmax
Exist?
No
Yes
Replace h2 by
1.8hmax -0.8h1
Δ h = h2-h1
>
=
(3)
Δh: 7000m
<
Have
secondary
maxima
been
checked?
Yes
No
Are
there
secondary
maxima?
No
Yes
Punch
Secondary
Maxima
(2)
<
Number of harmonics: 9
=
Reduce number
of harmonics
by one
h̄ = h1+h2
2
Δh̄ = h̄ - hmax
>
Number of harmonics: 6
D̄ = average direction
between h1 and h2
(2)
=
V̄ = 0.9 Vmax
Find D
(Vmax)
Punch Station No., Date, Time,
Vmax, D(Vmax), H(Vmax), h1, h2,
Δh, h̄, Δh̄, V̄, D̄
(1)

SYMBOL DEFINITIONS

Main Program

Input:

1. NS - station numbers
2. STAEL - station elevations
3. INOS - first station number for computation
4. INYRMO - first year and month for computation
5. IMDAHR - first day and hour for computation
6. NOS - current station number
7. NYRMO - current year and month
8. MDAHR - current day and hour
9. MIN - first minute of data on each card
10. ANBR - alphanumeric input of data (needed to read fields of eleven punches indicating missing data)
11. ALT - last altitude of data on card
12. NDELVV - data time interval for card in minutes (1 or 2)
13. NUNIT - indicates if data in knots or mps
14. NH - indicates if height is for last minute on card or one minute earlier, identifies last card of sounding

Output:

1. IVMAX, VMAX - maximum wind speed (punched as wind speed X ten)
2. IDMAX, DDN-direction of VMAX
3. IHMAX, HMAX - height of VMAX
4. IDH, DH - thickness of LMW
5. IHB, HB - average height of LMW
6. IDIR, DIR - average wind direction for LMW
7. NR - number of harmonics used in harmonic analysis
8. IVV - wind speed at secondary maxima X ten
9. IHM1, HM1 - height of secondary maxima
10. IH1, H1 - lower height of LMW
11. IH2, H2 - upper height of LMW
12. IDHB, DHB - difference between HB and HMAX
13. IVB, VB - 0.9 VMAX
14. DD - wind directions (after interpolation for missing minutes)
15. VV - wind speeds (after interpolation for missing minutes)

Others:

1. V- wind speeds (computed from ANBR)
2. D- wind directions (computed from ANBR)
3. LC - last card of sounding control
4. VMAX8 - 0.8 VMAX
5. NN - number of wind speeds and directions after harmonic analysis
6. C - coefficients for harmonic analysis
7. A - 15th point below VMAX} used in checking for baratropic wind
8. B - 15th point above VMAX}
9. SN - sine functions used in harmonic analysis
10. G - wind speed minus linear terms for harmonic analysis
11. DELTH - average height increase in sounding per minute

SUBROUTINE VALT

Call list:

1. V - value of data at desired altitude
2. ALT - altitude of needed value
3. DELTH - average height difference between data points
4. VV - data from which to choose needed point
5. K - indicates whether VV is wind speed or wind direction
6. N - number of data points

SUBROUTINE ROUND

Call list:

1. IVV - value of VV after sounding and representing as a fixed point number
2. VV - value to be rounded

COMPUTER TIME

Error checking, harmonic analysis and extraction of LMW parameters consumes approximately 1 second on the average per station, per map time, of IBM 7090 computer time.

```
C     LMW
      DIMENSIONVV( 64),DD( 64),NH(12),ALT(12),MIN(12),NDELVV(12),D(96)
     1,G(60),C(9),NS(74),STAEL(74),NI(2),MI(2),SN(9,60),ANBR(48),V(96)
      READ INPUT TAPE 5,4,(NS(I),STAEL(I),I=1,74)
 4    FORMAT(I5,F5.0)
      READ INPUT TAPE 5,12,INOS,INYRMO,IMDAHR
 12   FORMAT(I5,2I4)
 1050 READ INPUT TAPE 4,12,NOS,NYRMO,MDAHR
      IF(INOS-NOS)1050,1035,1050
 1035 IF(INYRMO-NYRMO)1050,1040,1050
 1040 IF(IMDAHR-MDAHR)1050,1045,1050
 1045 BACKSPACE4
      AMINUS=1.0
 1    DO 10 I=1,64
      VV(I)=0.0
 10   DD(I)=0.0
      DO 11 I=1,96
      D(I)=0.0
 11   V(I)=0.0
      DO 710 J=1,8
      MIN(J)=0
      ALT(J)=0.0
      NDELVV(J)=0
 710  NH(J)=0
      IL=1
      IU=8
      J=1
      READ INPUT TAPE 4,2,NOS,NYRMO,MDAHR,MIN(J),(ANBR(K),K=1,48    ),ALT
     1(J),NDELVV(J),NUNIT,NH(J)
 2    FORMAT(I5,2I4,I3,48F1.0          ,F5.0,3I1)
      IF(NOS-99999)50,285,285
 285  END FILE 8
      END FILE 8
      END FILE 8
      REWIND 8
      CALL EXIT
 50   I=IL
      DO 1600 K=1,48,6
      ANB=ANBR(K)
      IF(SIGNF(AMINUS,ANB))1605,1610,1610
 1605 D(I)=0.0
      V(I)=0.0
      GO TO 1600
 1610 D(I)=ANBR(K)*100.0+ANBR(K+1)*10.0+ANBR(K+2)
      V(I)=(ANBR(K+3)*100.0+ANBR(K+4)*10.0+ANBR(K+5))/10.0
 1600 I=I+1
      IF(NH(J)-1)85,90,95
 85   LC=0
      GO TO 100
 90   NH(J)=-0
      LC=1
      GO TO 100
 95   NH(J)=0
      LC=1
 100  IF(J-1)35,35,40
 40   IF(NOS-NNOS)1000,55,1000
```

```
55      IF(NYRMO-NNYRMO)1005,65,1005
65      IF(MDAHR-MMDAHR)1010,75,1010
75      IF(MIN(J)-MIN(J-1))105, 35,35
105     K=J-2
        KK=0
130     IF(K)135,135,125
125     KK=KK+1
        IF(MIN(J)-MIN(K))115,115,110
135     KK=KK+1
110     K=K+1
        KK=KK*8
        DO 120 I=IL,IU
        A=D(I)
        IKK=I-KK
        D(I)=D(I KK)
        D(I KK)=A
        A=V(I)
        V(I)=V(I KK)
120     V(I KK)=A
        A=MIN(J)
        MIN(J)=MIN(K)
        MIN(K)=A
        A=ALT(J)
        ALT(J)=ALT(K)
        ALT(K)=A
        N=NDELVV(J)
        NDELVV(J)=NDELVV(K)
        NDELVV(K)=N
        GO TO 75
115     K=K-1
        GO TO 130
35      IF(LC)30,30,45
30      IL=IL+8
        IU=IU+8
        J=J+1
        READ INPUT TAPE 4,2,NNOS,NNYRMO,MMDAHR,MIN(J),(ANBR(K),K=1,48    ),
       1ALT(J),NDELVV(J),NUNIT,NH(J)
        GO TO 50
45      IF(ALT(J)-9000.0)15,80,80
15      WRITE OUTPUT TAPE 6,3,NOS,NYRMO,MDAHR
3       FORMAT(29H LAST ALTITUDE LESS THAN 9000317)
        GO TO 1
80      IF(SENSE SWITCH 1)675,680
675     WRITE OUTPUT TAPE 6,9,(MIN(JJ),JJ=1,8),(D(I),V(I),I=1,64)
680     I=1
        K=8
        DO 20 JJ=1,J
        II=MIN(JJ)+1
        IF(II-64)145,145,21
145     DD(II)=D(I)
        VV(II)=V(I)
        I=I+1
        IF(I-K)150,150,20
150     IF(NDELVV(JJ)-1)25,25,140
140     II=II+1
25      II=II+1
```

```
      IF(II- 64)145,145,211
211   II=64
      GO TO 210
20    K=K+8
      JJ=J
210   NCNT=0
      DO 160 I=1,II
      IF(DD(I)-360.0)181,181,180
181   IF(DD(I))155,155,170
155   IF(VV(I))165,165,1025
165   NCNT=NCNT+1
      GO TO 160
170   IF(VV(I))1025,1025,175
175   IF(DD(I)-360.0)185,185,180
180   IF(DD(I)-860.0)190,190,1030
190   DD(I)=DD(I)-500.0
      IF(NUNIT)191,191,192
191   VV(I)=VV(I)+100.0
      GO TO 185
192   VV(I)=VV(I)+10.0
185   IF(NCNT)160,160,195
195   IK=I-NCNT-1
      IF(IK)1305,1300,1305
1300  IK=1
      NCNT=NCNT-1
1305  K=1
      N270=0
      D(1)=DD( IK)
      D(2)=DD(I)
      DO 1100 JK=1,2
      IF(D(JK)-270.0)1100,1105,1105
1105  N270=N270+1
1100  CONTINUE
      IF(N270)200,200,1110
1110  DO 1115 JK=1,2
      IF(D(JK)-90.0)1120,1120,1115
1120  D(JK)=D(JK)+360.0
1115  CONTINUE
200   IKK=IK+K
      VV(IKK)=VV( IK)+(VV(I)-VV( IK))*FLOATF(K)/(FLOATF(NCNT)+1.0)
      DD(IKK)=D(1)+(D(2)-D(1))*FLOATF(K)/(FLOATF(NCNT)+1.0)
      DDN=DD(IKK)
      DD(IKK)=MODF(DDN,360.0)
      K=K+1
      IF(IK+K-I)200,205,205
205   NCNT=0
160   CONTINUE
      N=II-NCNT
      IF(NUNIT)215,215,220
220   DO 225 I=1,N
225   VV(I)=VV(I)*5.14791
215   NN=N-4
      IC=1
      IF(SENSE SWITCH 2)1430,1435
1430  DO 1440 I=1,9
1440  C(I)=0.0
```

```
      GO TO 1445
1435  DO 230 I=2,NN
      A=(VV(I-1)+VV(I+1))/2.0
      IF(ABSF(VV(I)-A)-15.00)230,230,235
235   VV(I)=A
230   CONTINUE
      IF(SENSE SWITCH 1)665,670
665   WRITE OUTPUT TAPE 6,9,(DD(I),VV(I),I=1,N)
9     FORMAT(8F10.1)
670   J1=J
      VMAX=VV(1)
      IM=1
      DO 1505 I=2,N
      IF(VMAX-VV(I))1510,1505,1505
1510  VMAX=VV(I)
      IM=I
1505  CONTINUE
      A=VMAX-VV(IM-15)
      IF(A-15.0)1515,671,671
1515  IF(IM+15-NN)1520,1520,671
1520  B=VMAX-VV(IM+15)
      IF(B-15.0)1525,671,671
1525  IC=2
      GO TO 1430
671   DO 1500 I=1,9
      DO 1500 J=1,NN
1500  SN(I,J)=SINF(3.1415927*FLOATF(I)*FLOATF(J-1)/FLOATF(NN-1))
      A=VV(1)
      B=0.0
      DO 240 I=1,9
      NII=N-I+1
240   B=B+VV(NII)
      VV(NN)=B/9.0
      B=(B/9.0-VV(1))/(FLOATF(N)-5.0)
      DO 245 I=1,NN
245   G(I)=VV(I)-A-B*(FLOATF(I)-1.0)
      E=2.0/FLOATF(NN-1)
      DO 250 I=1,9
      C(I)=0.0
      DO 255 J=1,NN
255   C(I)=C(I)+G(J)*SN(I,J)
250   C(I)=E*C(I)
      DO 260 J=1,NN
      E=0.0
      DO 265 I=1,9
265   E=E+C(I)*SN(I,J)
260   VV(J)=A+B*FLOATF(J-1)+E
1445  DO 270 I=1,74
      IF(NOS-NS(I))270,275,270
275   IH=I
      GO TO 280
270   CONTINUE
280   NIN=N-1
      IF(II- 64)1315,1310,1310
1310  NIN=MIN(J1)-NDELVV(J1)
      JJ=J1-1
```

```
1315 IF(NUNIT)666,666,672
672  DELTH=ALT(JJ)/FLOATF(N1N)
     GO TO 676
666  DELTH=(ALT(JJ)-STAEL(IH))/FLOATF(N1N)
676  GO TO (690,296),IC
690  IA=1
575  VMAX=VV(1)
     IM=1
     DO 295 I=2,NN
     IF(VMAX-VV(I))300,295,295
300  VMAX=VV(I)
     IM=I
295  CONTINUE
296  HMAX=DELTH*FLOATF(IM-1)+STAEL(IH)
     IF(SENSE SWITCH 1)1400,1405
1400 WRITE OUTPUT TAPE 6,1401,VMAX,HMAX,IM
1401 FORMAT(2F15.2,I5)
1405 GO TO (1406,315),IC
1406 GO TO (580,395),IA
580  IF(IM-NN)310,305,305
305  VMAX=VMAX*10.0
     DDN=DD(NN)
     CALL ROUND(IVMAX,VMAX)
     CALL ROUND(IDMAX,DDN    )
     CALL ROUND(IHMAX,HMAX)
     WRITE OUTPUT TAPE 7,5,NOS,NYRMO,MDAHR,IVMAX,IDMAX,IHMAX
5    FORMAT(I6,3I5,I4,I6)
     GO TO 1
310  A=VMAX-VV(IM-15)
     IF(A-15.0)1205,395,395
1205 IF(IM+15-NN)1210,1210,395
1210 B=VMAX-VV(IM+15)
     IF(B-15.0)315,395,395
315  DH=7000.0
     HB=20000.0
     CALL VALT(D8,8000.0,DELTH,DD,1,NN)
     CALL VALT(D10,10000.0,DELTH,DD,1,NN)
     CALL VALT(D12,12000.0,DELTH,DD,1,NN)
     IF(SENSE SWITCH 1)1410,1415
1410 WRITE OUTPUT TAPE 6,1411,D8,D10,D12
1411 FORMAT(3F10.2)
1415 IF(D12-D10)345,320,320
320  PHI1=D12
     IF(D10-D8)330,325,325
325  PHI2=D10
     PHI3=D8
     GO TO 370
330  PHI3=D10
     IF(D12-D8)340,335,335
335  PHI2=D8
     GO TO 370
340  PHI1=D8
     PHI2=D12
     GO TO 370
345  PHI1=D10
     IF(D12-D8)355,350,350
```

```
350   PHI2=D12
      PHI3=D8
      GO TO 370
355   PHI3=D12
      IF(D10-D8)365,360,360
360   PHI2=D8
      GO TO 370
365   PHI1=D8
      PHI2=D10
370   IF(PHI1-PHI2-180.0)375,375,390
375   IF(PHI1-PHI3-180.0)380,380,385
385   PHI3=PHI3+360.0
      GO TO 380
390   PHI1=PHI1-360.0
380   DIR=(PHI1+PHI2+PHI3)/3.0
      DIR=MODF(DIR,360.0)
      VMAX=10.0*VMAX
      CALL ROUND(IVMAX,VMAX)
      CALL ROUND(IDH,DH)
      CALL ROUND(IHB,HB)
      CALL ROUND(IHMAX,HMAX)
      CALL ROUND(IDIR,DIR)
      DDN=DD(IM)
      CALL ROUND(IDMAX,DDN)
      NR=1
      WRITE OUTPUT TAPE 7,6,NOS,NYRMO,MDAHR,IVMAX,IDMAX,IHMAX,IDH,IHB,
     1IR,NR
6     FORMAT(I6,3I5,I4,I6,12X,2I6,11X,I4,I2)
      GO TO 1
395   VMAX8=.8*VMAX
      DO 400 I=1,IM
      IF(VMAX8-VV(I))405,405,400
405   IM8=I
      GO TO 410
400   CONTINUE
410   DT1=(VMAX8-VV(IM8-1))/(VV(IM8)-VV(IM8-1))
415   H1=DELTH*(FLOATF(IM8-2)+DT1)+STAEL(IH)
      DO 425 I=IM,NN
      IF(VV(I)-VMAX8)430,430,425
430   IM82=I
      GO TO 435
425   CONTINUE
      H2=1.8*HMAX-.8*H1
      DT2=0.0
      IM82=NN
      GO TO 450
435   DT2=(VMAX8-VV(IM82-1))/(VV(IM82)-VV(IM82-1))
445   H2=DELTH*(FLOATF(IM82-2)+DT2)+STAEL(IH)
450   DH=H2-H1
      IF(SENSE SWITCH 1)1420,1425
1420  WRITE OUTPUT TAPE 6,1421,VMAX8,DT1,H1,DT2,H2,DH,IM8,IM82
1421  FORMAT(6F11.3,2I5)
1425  GO TO (585,550),IA
585   IF(DH-7000.0)455,455,315
455   NR=9
      N1=NN-1
```

```
      N2=5000.0/DELTH
570   NMAX=0
      IB=1
      K=0
      NMIN=1
      MI(NMIN)=N2
      M=0
      DO 515 I=N2,N1
      IF(K)490,490,480
490   IF(VV(I+1)-VV(I))465,515,515
465   NMAX=NMAX+1
      NI(NMAX)=I
      K=1
      GO TO 460
470   M1=NI(1)
      M2=NI(2)
      HM1=DELTH*FLOATF(M1-1)+STAEL(IH)
      HM2=DELTH*FLOATF(M2-1)+STAEL(IH)
      IF(HM2-HM1-4500.0)535,475,475
475   DDN=VV(M1)*10.0
      CALL ROUND(IVV,DDN    )
      CALL ROUND(IHM1,HM1)
      WRITE OUTPUT TAPE 8,7,NOS,NYRMO,MDAHR,IVV,IHM1
7     FORMAT(I6,3I5,I6)
      NMAX=1
      NI(1)=M2
      GO TO 515
480   IF(VV(I)-VV(I+1))485,460,460
485   K=0
      NMIN=NMIN+1
      MI(NMIN)=I
      IF(NMIN-2)460,495,495
495   M1=NI(NMAX)
      M2=MI(1)
      IF(M1-N2)525,520,525
520   M1=M1-1
      IF(M1)540,540,530
530   IF(VV(M1)-VV(M1+1))540,520,520
540   M2=MI(2)
      IF(VV(M1+1)-VV(M2)-5.0)510,545,545
545   NI(NMAX)=M1+1
      GO TO 505
525   IF(VV(M1)-VV(M2)-5.0)510,500,500
500   M2=MI(2)
      IF(VV(M1)-VV(M2)-5.0)510,505,505
505   M=M+1
      NMIN=1
      MI(1)=MI(2)
      IF(M-2)515,470,470
510   NMAX=NMAX-1
      NMIN=1
      MI(1)=MI(2)
      GO TO(460,515),IB
460   IF(I-N1)515,486,486
486   IB=2
      GO TO 485
```

```
515   CONTINUE
      IF(NMAX)1550,1550,1555
1555  M1=NI(NMAX)
      HH1=DELTH*FLOATF(M1-1)+STAEL(IH)
      DDN=VV(M1)*10.0
      CALL ROUND(IVV,DDN)
      CALL ROUND(IHM1,HM1)
      WRITE OUTPUT TAPE 8,7,NOS,NYRMO,MDAHR,IVV,IHM1
1550  IF(NR-9)555,550,550
535   IF(NR-6)555,555,536
536   NR=NR-1
      IF(NR-6)555,560,560
560   I=NR+1
      DO 565 J=1,NN
565   VV(J)=VV(J)-C(I)*SN(I,J)
      GO TO 570
555   IA=2
      GO TO 575
550   HB=(H1+H2)/2.0
      DHB=HB-HMAX
      IF(DT1-.5)590,595,595
590   IM8=IM8-1
595   IF(DT2-.5)600,605,605
600   IM82=IM82-1
605   N90=0
      N270=0
      DO 610 J=IM8,IM82
      IF(DD(J)-90.0)615,615,620
615   N90=N90+1
      GO TO 610
620   IF'ЭD(J)-270.0)610,625,625
625   N270=N270+1
610   CONTINUE
      SDD=0.0
      IF(N90)640,640,635
635   IF(N270)640,640,630
630   DO 645 J=IM8,IM82
      IF(DD(J)-90.0)650,650,645
650   DD(J)=DD(J)+360.0
645   SDD=SDD+DD(J)
      GO TO 660
640   DO 655 J=IM8,IM82
655   SDD=SDD+DD(J)
660   NJ=IM82-IM8+1
      DIR=SDD/FLOATF(NJ)
      DIR=MODF(DIR,360.0)
      VB=.9*VMAX
      VMAX=VMAX*10.0
      CALL ROUND(IVMAX,VMAX)
      DDN=DD(IM)
      CALL ROUND(IDMAX,DDN)
      CALL ROUND(IHMAX,HMAX)
      CALL ROUND(IH1,H1)
      CALL ROUND(IH2,H2)
      CALL ROUND(IDH,DH)
      CALL ROUND(IHB,HB)
```

```
      CALL ROUND(IDHB,DHB)
      VB=VB*10.0
      CALL ROUND(IVB,VB)
      CALL ROUND(IDIR,DIR)
      WRITE OUTPUT TAPE 7,8,NOS,NYRMO,MDAHR,IVMAX,IDMAX,IHMAX,IH1,IH2,ID
     1H,IHB,IDHB,IVB,IDIR,NR
8     FORMAT(I6,3I5,I4,6I6,I5,I4,I2)
      GO TO 1
1000  WRITE OUTPUT TAPE 6,1001,NOS,NNOS
1001  FORMAT(19H ERROR, STATION NO 2I8)
      GO TO 1015
1005  WRITE OUTPUT TAPE 6,1006,NOS,NYRMO,NNYRMO
1006  FORMAT(21H ERROR, YEAR OR DATE I8,2I7)
      GO TO 1015
1010  WRITE OUTPUT TAPE 6,1011,NOS,NYRMO,MDAHR,MMDAHR
1011  FORMAT(20H ERROR, DAY OR HOUR I8,3I7)
1015  IF(LC-1)1020,1,1
1020  READ INPUT TAPE 4,1021,NHJ
1021  FORMAT(36X,35X,I1)
      IF(NHJ)1020,1020,1
1025  WRITE OUTPUT TAPE 6,1026,NOS,NYRMO,MDAHR,DD(I),VV(I),I
1026  FORMAT(14H ERROR, DD, VVI8,2I7,F5.0,F5.1,I4)
      GO TO 1
1030  WRITE OUTPUT TAPE 6,1031,NOS,NYRMO,MDAHR,DD(I),I
1031  FORMAT(27H ERROR, DD GREATER THAN 860I8,2I7,F5.0,I4)
      GO TO 1
      END
```

```
      SUBROUTINE VALT(V,ALT,DELTH,VV,K,N)
      DIMENSION VV(100)
      F=ALT/DELTH+1.0
      I=F
      D=F-FLOATF(I)
      IF(I-N)51,55,55
55    V=VV(N)
      GO TO 20
51    IF(K)10,10,15
10    V=VV(I)+D*(VV(I+1)-VV(I))
      GO TO 20
15    IF(VV(I)-90.0)25,25,35
25    IF(VV(I+1)-270.0)10,30,30
30    VV(I)=VV(I)+360.0
50    V=VV(I)+D*(VV(I+1)-VV(I))
      V=MODF(V,360.0)
      GO TO 20
35    IF(VV(I)-270.0)10,40,40
40    IF(VV(I+1)-90.0)45,45,10
45    VV(I+1)=VV(I+1)+360.0
      GO TO 50
20    RETURN
      END
```

```
      SUBROUTINE ROUND(IVV,VV)
      IVV=VV
      FVV=IVV
      IF(VV-FVV-0.5)10   ,15,15
   15 IVV=IVV+1
   10 RETURN
      END
```

Appendix 3: Final print-out of the layer of maximum wind parameters

The columns may be ident:'ied as follows:

1. Station identification number
2. Year and month
3. Day and hour
4. V_{max} = maximum speed of smoothed wind profile
5. D_{max} = wind direction reported at level of maximum speed
6. h_{max} = height of wind maximum
7. h_1 = lower boundary } of LMW
8. h_2 = upper boundary } of LMW
9. $h_2 - h_1 = h$ = thickness of LMW
10. $\frac{h_1 + h_2}{2} = \bar{h}$ = height of LMW
11. $\bar{h} - h_{max}$ = height difference between height of LMW and h_{max}; serves as indicator of asymmetry of vertical wind shear
12. $0.9\ V_{max}$ = mean speed of LMW
13. $\bar{D}$ = mean direction of LMW
14. N = number of harmonics used in computing the smoothed profile:
    N = 6: number of harmonics used for vertical smoothing in baroclinic case
    = 1: barotropic case
    = 0: if $V_{max} = V_{last}$

The following table contains a typical set of output data:

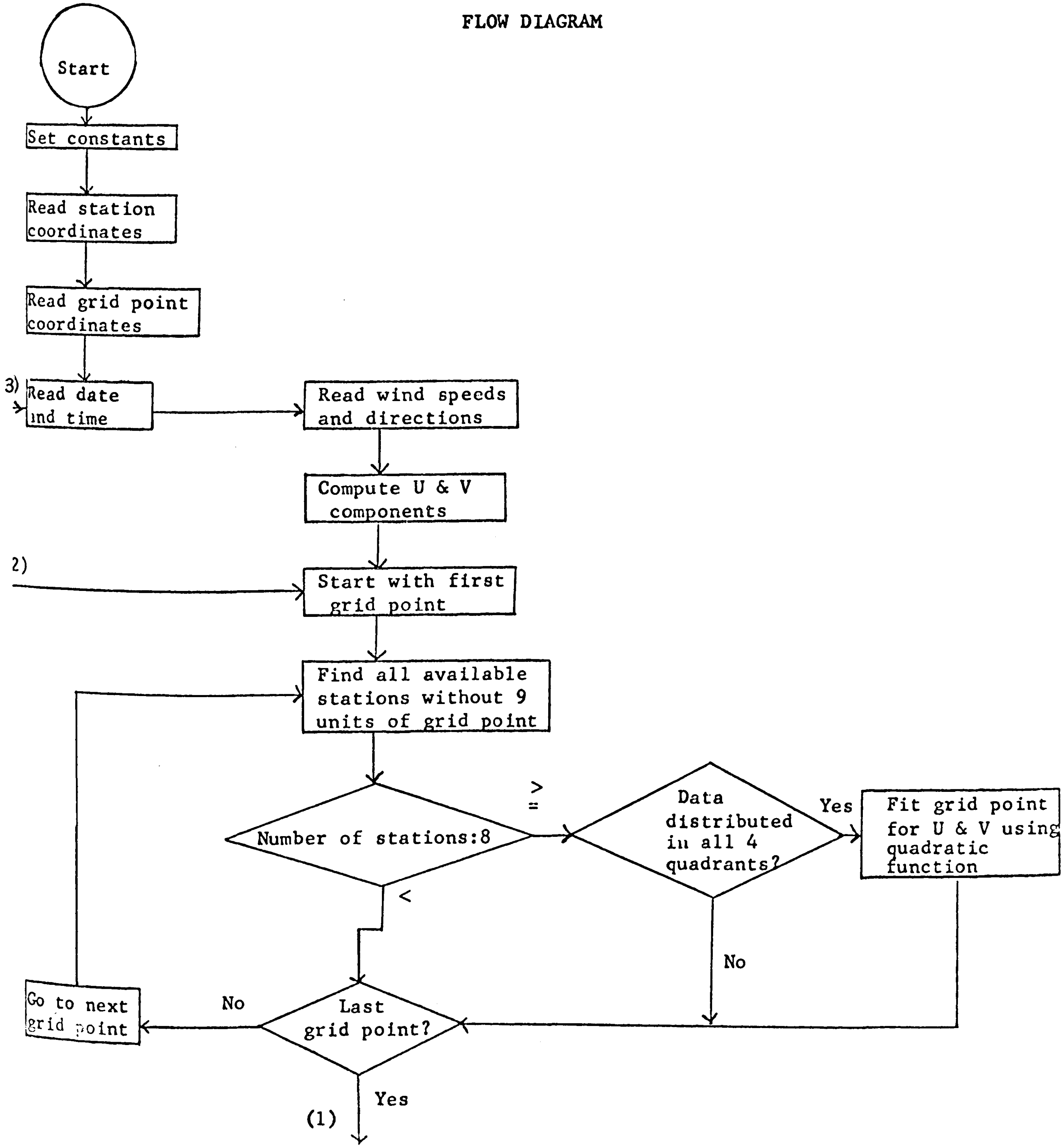
a #	yr & mo	day & hr	V_{max}	D_{max}	H_{max}	H1	H2	DH	HB	DHB	VB	DIR	NR
062	6101	1000	25.4	263	11335	7825	14142	6317	10984	-350	229	240	9
062	6101	1012	30.8	215	10027	8469	11937	3468	10203	175	277	227	9
062	6101	1100	42.1	32	10705	8612	12276	3664	10444	-261	379	30	9
008	6101	1400	19.9	297	11228			7000	20000			258	1
008	6101	1412	26.5	277	6811			7000	20000			288	1
131	6107	2712	337	254	13032	10723	14583	3860	12653	-379	303	251	9
131	6107	2800	407	255	11729	10073	13490	3417	11782	53	366	256	9
131	6107	2812	343	243	11873	9551	14571	5020	12061	187	309	243	9
131	6107	2900	497	237	9150	8193	9915	1723	9054	- 95	447	238	9
131	6107	2912	439	268	11072								
131	6107	3000	429	246	10917	9455	12086	2631	10771	-146	386	240	9
143	6107	2812	558	261	12338	10766	13954	3188	12360	22	502	257	9
143	6107	2900	377	237	7549	5933	13060	7126	9497	1948	339	241	7
143	6107	2912	781	247	11668	10100	13258	3158	11679	12	703	245	9
157	6107	700	318	196	12188			7000	20000			195	1
157	6107	712	428	194	11195	9477	12775	3298	11126	- 68	385	197	9

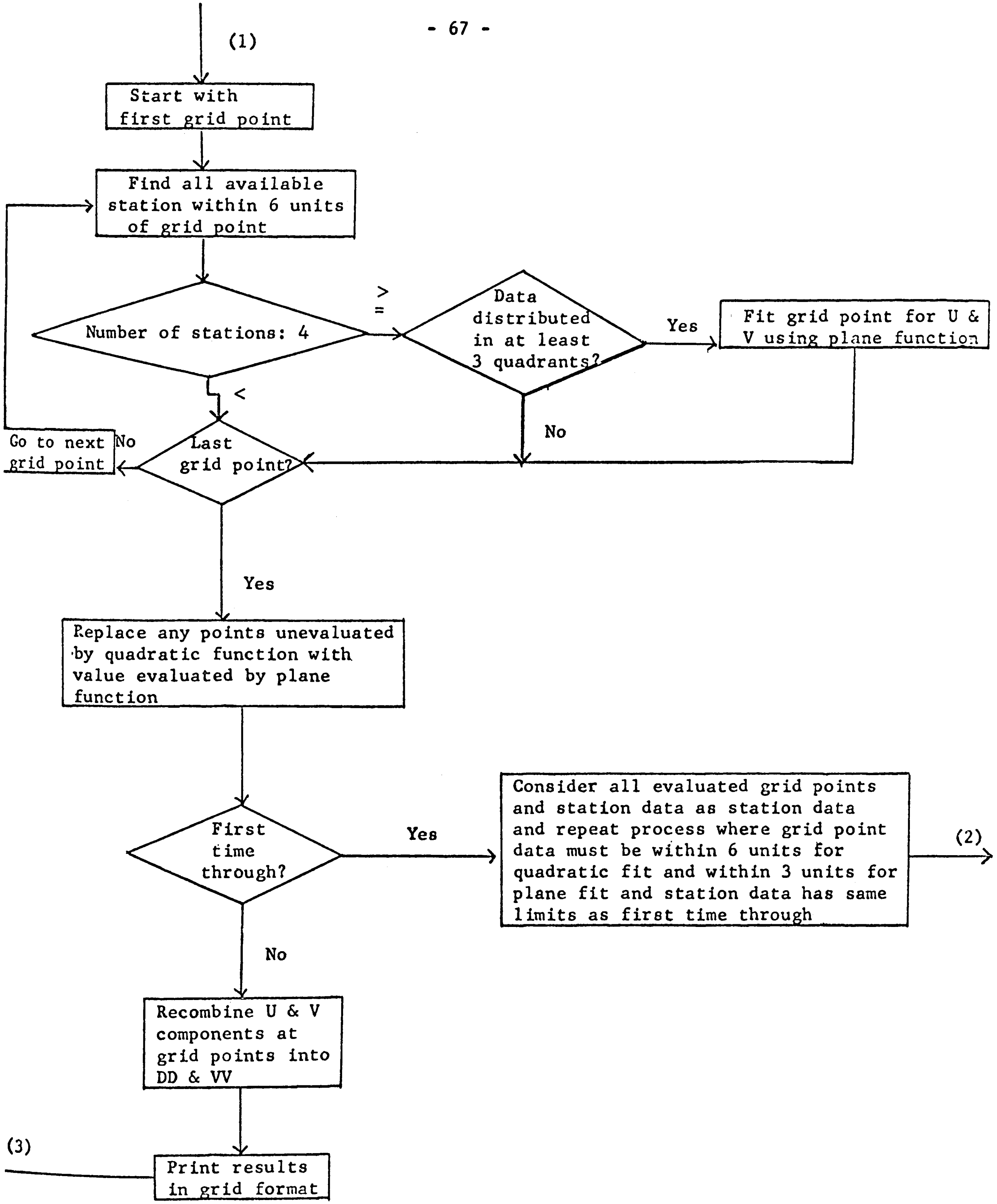
Appendix 4: Programs for horizontal analysis of Layer of Maximum Wind parameters.

The programs "GRID" and "GRIDHT" compute horizontal analyses of LMW parameters by fitting the data to specified grid points. A quadratic function is used to compute each grid point if enough data exists, otherwise a plane function is used.

Program "GRID" is used for the horizontal analysis of wind speed and wind direction.

FLOW DIAGRAM





(1)
Start with first grid point
Find all available station within 6 units of grid point
Number of stations: 4
>=
Data distributed in at least 3 quadrants?
Yes
Fit grid point for U & V using plane function
No
<
Last grid point?
No
Go to next grid point
Yes
Replace any points unevaluated by quadratic function with value evaluated by plane function
First time through?
Yes
Consider all evaluated grid points and station data as station data and repeat process where grid point data must be within 6 units for quadratic fit and within 3 units for plane fit and station data has same limits as first time through
(2)
No
Recombine U & V components at grid points into DD & VV
(3)
Print results in grid format

SYMBOL DEFINITIONS

All variables which are stored in common are defined in the main program or in the first subroutine in which they appear.

Main Program

Input:

1. FDATE - first date for computation
2. FTIME - first time for computation
3. KA - map number for print-out
4. SDATE - current date
5. STIME - current time
6. S - station number

Others:

1. IPT - input tape number
2. MPT - output tape number
3. SH - control character for last data card for date and time (99999)
4. MFP - control character for output

SUBROUTINE WHIT

Output:

1. GLAT - grid point latitudes
2. GLON - grid point longitudes
3. RU5Q - U component, quadratic fit
4. RU5P - U component, plane fit
5. RV5Q - V component, quadratic fit
6. RV5P - V component, plane fit

SUBROUTINE P1

Input:

1. D1 - date
2. D2 - time
3. I50VV, A50VV - wind speeds
4. I50DD, A50DD - wind directions
5. I50H, A50H - height

Output:

1. V50 - V components
2. U50 - U components
3. JS - stores station subscripts
4. IOA - counts number of stations with data for current date and time

Others:

1. IO, LO - counts number of input stations
2. NSN - possible station numbers
3. JSN - subscript of station

SUBROUTINE P3

Output:

1. KGP - grid point number
2. U - U components available for computing grid point
3. V - V components available for computing grid point
4. X - longitude distances from grid point to data point
5. Y - latitude distances from grid point to data point
6. L, LS, IN - number of data points available for computing grid point

Others:
1. UGPQ - U component, quadratic fit
2. VGPQ - V component, quadratic fit
3. Q1T, Q2T, Q3T, Q4T - used in checking distribution of data
4. Q1, Q2, Q3, Q4 - used in checking distribution of data
5. P - U & V components at grid points combined with date for output (grid points used as data second time through)
6. QLATB - maximum latitude distance between grid point and data point for quadratic fit
7. QLONB - maximum longitude distance between grid point and data point for quadratic fit
8. SLA - station latitudes for all stations
9. SLN - station longitudes for all stations
10. SQ - number of quadrants data is in around grid point
11. NSQB - minimum number of data points necessary to compute grid point using quadratic function
12. B, D - matrices used in fitting quadratic function by method of least squares
13. XY, XX, YY, XXY, XXX, XYY, YYY, XXYY, XXXY, XYYY, XXXX, YYYY, VX, VY, VXY, VXX, VYY - used in computing matrix D
14. UX, UY, UXY, UXX, UYY - used in computing matrix B
15. DD - saves part of matrix D that contains products of X and Y
16. UORV - grid point value
17. UGPP - U component, plane fit
18. VGPP - V component, plane fit
19. PLATB - maximum latitude distance between grid point and data point for plane fit
20. PLONB - maximum longitude distance between grid point and data point for plane fit
21. NSPB - minimum number of data points necessary to compute grid point using plane function
22. AP, BP - used in fitting plane function by method of least squares
23. SVX, SX, SY, SYY, SXY, SXX, SV, SU, SVY, SUX, SUY - used in computing AP and BP

SUBROUTINE P4

Output:
1. NANG - wind direction for grid point
2. NVEL - wind speed for grid point

Others:
1. RD5Q - current date
2. RT5Q - current time
3. CK - value given to missing points

SUBROUTINE P5

Input:
1. X - station latitude
2. Y - station longitude

Output:
1. SN - possible station numbers

Others:
1. RAD - constant to convert degrees to radians
2. RTD - constant to convert radians to degrees
3. A00 - not used

COMPUTER TIME

Objective wind analysis consumes approximately 45 seconds of IBM 7090 computer time, per map.

```
C   GRID
      COMMONO
      EQUIVALENCE(O(2421),IPT(1)),(O(2878),MPT(1),MFP(2)),(O(2879),KA(1)
     1),(O(2419),SH(1))
      DIMENSION O(3000)
      IPT=5
      MPT=6
      CALL P5
      READ INPUT TAPE 5,1,FDATE,FTIME,KA
 1    FORMAT(10X,A6,I2,I3)
 25   READ INPUT TAPE IPT,1,SDATE,STIME
      IF(FDATE-SDATE)15,10,15
 10   IF(FTIME-STIME)15,20,15
 15   READ INPUT TAPE IPT,2,S
 2    FORMAT(1A5)
      IF(S-SH)15,25,15
 20   BACKSPACE IPT
 30   MFP=0
      CALL WHIT
      KA=KA+1
      GO TO 30
      END


      SUBROUTINE WHIT
      COMMON O
      DIMENSION O(3000)
      EQUIVALENCE (SDATE,RD5Q),(STIME,RT5Q)
      EQUIVALENCE(O(2878),MPT(1))
      EQUIVALENCE(O(808),P(808),NVEL(402),NANG(201)),
     A          (O(2421),ISN(2),IPT(1),SH(3),IT(4),RAD(5),CK(6))
     B,(O(2876),          GLON(201),GLAT(402))
      EQUIVALENCE(O(1617), RU5Q(809),  RV5Q(608)
     A      ,  RU5P(407),  RV5P(206)
     C      ,   RTD(  5),  RD5Q(  4),  RT5Q(  3))
      DIMENSION                RU5Q(201),  RV5Q(201),
     A          RU5P(201),  RV5P(201),
     C                                       P(0406),  NVEL(201),  NANG(201)
      DIMENSION
     A GLAT(201),GLON(201)
      READ INPUT TAPE IPT, 2001, SDATE, STIME
 2001 FORMAT(10X,A6,I2)
      CALL P1
      IF(SENSE SWITCH 2)4000,4005
 4000 WRITE OUTPUT TAPE 6,4010,(GLAT(K),GLON(K),K=1,201)
 4010 FORMAT(10F10.2)
 4005 CALL P3
      IF(SENSE SWITCH 2)3000,3005
 3000 WRITE OUTPUT TAPE 6,3001,(RU5Q(I),RU5P(I),RV5Q(I),RV5P(I),I=1,201)
 3001 FORMAT(4F15.2)
 3005 CALL P4
      CALL P3
      IF(SENSE SWITCH 2)5070,5075
 5070 WRITE OUTPUT TAPE 6,3001,(RU5Q(I),RU5P(I),RV5Q(I),RV5P(I),I=1,201)
 5075 CALL P4
      RETURN
      END
```

```
      SUBROUTINE P1
      COMMON O
      EQUIVALENCE(NS,IS)
      EQUIVALENCE(O(2880),LF(1))
      EQUIVALENCE(O(2878),MPT(1))
      EQUIVALENCE(O(2415),  SN( 800),  SLA( 700),  SLN( 600)
     A       ,                V50( 500),  U50( 400), A50H( 300)
     B       ,    IOA( 200),  JS( 100),  NSN( 800))
     C       ,    (IS,S),(ISH,SH),(O(2421),ISN(2),IPT(1),SH(3),IT(4)
     D       ,    RAD(5))
      DIMENSION               SN(0100),  SLA(0100), SLN(0100)
     A       ,                V50(0100),  U50(0100), A50H(0100)
     B       ,    IOA(0100),  JS(0100),  NSN(0100)
      IO=0
      LF=0
   10 CONTINUE
      READ INPUT TAPE IP1, 7,S,D1,D2,I50VV,I50DD,I50H
    7 FORMAT(1X,1A5,2(1X,1A4),115,114,116)
      IF(IS-ISH) 9,8,9
    9 CONTINUE
      DO11 I=1,ISN
      IF(NS-NSN(I)) 11,12,11
   11 CONTINUE
      GO TO 10
   12 CONTINUE
      JSN=I
      IO=IO+1
      LF=LF+1
      A50VV = FLOATF(I50VV)/10.0
      A50DD = FLOATF(I50DD)*RAD
      V50(LF) = -A50VV*COSF(A50DD)
      U50(LF) = -A50VV*SINF(A50DD)
      A50H(LF) = FLOATF(I50H)
      JS(LF)=JSN
      IOA(LF) = IO
      GOTO10
    8 CONTINUE
      IF(SENSE SWITCH 2)100,105
  100 WRITE OUTPUT TAPE 6,106,(V50(I),U50(I),A50H(I),JS(I),IOA(I),I=1,LF
     1)
  106 FORMAT(2F12.2,F15.2,2I5)
  105 RETURN
      END
```

```
      SUBROUTINE P3
      COMMON O
      EQUIVALENCE(O(2880),LF(1))
      EQUIVALENCE(O(2878),MPT(1))
      EQUIVALENCE(O(1617), RU5Q(809),  RV5Q(608)
     A       ,  RU5P(407),  RV5P(206),
     C                                       P(1617),NVEL(1211),NANG(1010)
     D       ,    RTD(  5),  RD5Q(   4),  RT5Q(   3)
     E      ),(O(2416),CK(6))
     F,(O(2465),D(44),L(1),UORV(2))
     G,(O(2474),QLATB(1),QLONB(2),PLATE(3),PLONB(4),NSQB(5),NSPB(6))
      DIMENSION                  RU5Q(201),  RV5Q(201)
     A       ,  RU5P(201),  RV5P(201),
     C                                       P(0406),  NVEL(201),  NANG(201)
     D,                    U(100),B(6),D(6,7),DD(6,6),UGPP(201),VGPP(201)
     E,UGPQ(201),VGPQ(201)
      EQUIVALENCE(O(2415),  SN( 800),  SLA( 700),  SLN( 600)
     A       ,                  V50( 500),  U50( 400), A50H( 300)
     B       ,   IOA( 200),  JS( 100),  NSN(800))
     C,(IS,S),(ISH,SH),(O(2421),          IPT(1),SH(3),IT(4)
     D,RAD(5))
     E,(O(2876),         GLON(201),GLAT(402)),(O(2877),MFP(1))
     F                        ,(O(406),P(406))
      DIMENSION                 SN(0100),  SLA(0100), SLN(0100)
     A       ,                  V50(0100),  U50(0100), A50H(0100)
     B,IOA(0100),JS(0100),NSN(0100),                         V(100),
     C           X(100),Y(100),ISS(100)
     D,GLAT(201),GLON(201)
      DO 93 IFT=1,1
      DO 213 I= 1,201
      UGPQ(I)= 999.99
      VGPQ(I)= 999.99
213   CONTINUE
      DO 92 KGP=1,201
      Q1T=0.
      Q1=0.
      Q2T=0.
      Q2=0.
      Q3T=0.
      Q3=0.
      Q4T=0.
      Q4=0.
      L=0
      IF(MFP)7005,7000,7005
 7005 J=5
      DO 7010 I=1,201
      IF(P(J)-999.99)7015,7010,7015
 7015 IF(6.0-ABSF(GLAT(KGP)-GLAT(I)))7010,7020,7020
 7020 CONTINUE
      IF(6.0-ABSF(GLON(KGP)-GLON(I)))7010,7025,7025
 7025 CONTINUE
      U(L+1)=P(J)
      V(L+1)=P(J+1)
      L=L+1
      ISS(L)=I
      X(L)=(GLON(I)-GLON(KGP))
```

```
      Y(L)=GLAT(I)-GLAT(KGP)
 7010 J=J+2
 7000 DO 5000 I= 1,LF
      ISN= JS(I)
      IF( QLATB - ABSF(GLAT(KGP) - SLA(ISN)))  5000,5001,5001
5001  CONTINUE
      IF( QLONB - ABSF(GLON(KGP) - SLN(ISN)))  5000,5002,5002
5002  CONTINUE
      IF(100.-ABSF(U50(I))) 5000,5000,73
73    IF(100.-ABSF(V50(I))) 5000,5000,652
652   CONTINUE
      U(L+1)=U50(I)
      V(L+1)=V50(I)
      GO TO 65
65    CONTINUE
      L=L+1
      ISS(L)= JS(I)
      X(L)=(SLN(ISN)-GLON(KGP))
      Y(L)= SLA(ISN)-GLAT(KGP)
5000  CONTINUE
      DO 5005 I= 1,L
      IF(X(I)) 5006,5007,5007
5006  CONTINUE
      IF(Y(I)) 5008,5009,5009
5008  CONTINUE
      Q3T=1.
      Q3  =1.+Q3
      GO TO 5005
5009  CONTINUE
      Q2T=1.
      Q2  =1.+Q2
      GO TO 5005
5007  CONTINUE
      IF(Y(I)) 5011,5012,5012
5011  CONTINUE
      Q4T=1.
      Q4  =1.+Q4
      GOTO 5005
5012  CONTINUE
      Q1T=1.
      Q1=1.+Q1
5005  CONTINUE
      LS=L
      SQ= Q1T+Q2T+Q3T+Q4T
      IF(NSQB-L) 5003,5003,5004
5003  CONTINUE
      IF(SQ-4.)5010,5013,5013
5013  CONTINUE
      IF(SENSE SWITCH 2)6000,6005
 6000 WRITE OUTPUT TAPE 6,6001,KGP,(U(I),V(I),X(I),Y(I),I=1,L)
 6001 FORMAT(I5/(4F15.2))
 6005 DO 5  I =1,6
      B(I)=0
      DO 5  J =1,7
      D(I,J)=0.
5     CONTINUE
```

```
DO 90 L=1,LS
XY   = X(L) * Y(L)
XX   = X(L) * X(L)
YY   = Y(L) * Y(L)
XXY  = X(L) * X(L) * Y(L)
XXX  = X(L) * X(L) * X(L)
XYY  = X(L) * Y(L) * Y(L)
YYY  = Y(L) * Y(L) * Y(L)
XXYY = X(L) * X(L) * Y(L) * Y(L)
XXXY = X(L) * X(L) * X(L) * Y(L)
XYYY = X(L) * Y(L) * Y(L) * Y(L)
XXXX = X(L) * X(L) * X(L) * X(L)
YYYY = Y(L) * Y(L) * Y(L) * Y(L)
UX   = U(L) * X(L)
UY   = U(L) * Y(L)
UXY  = U(L) * X(L) * Y(L)
UXX  = U(L) * X(L) * X(L)
UYY  = U(L) * Y(L) * Y(L)
VX   = V(L) * X(L)
VY   = V(L) * Y(L)
VXY  = V(L) * X(L) * Y(L)
VXX  = V(L) * X(L) * X(L)
VYY  = V(L) * Y(L) * Y(L)
D(1,1) = D(1,1) + X(L)
D(2,1) = D(2,1) + XX
D(3,1) = D(3,1) + XY
D(4,1) = D(4,1) + XXY
D(5,1) = D(5,1) + XXX
D(6,1) = D(6,1) + XYY
D(1,2) = D(1,2) + Y(L)
D(2,2) = D(2,2) + XY
D(3,2) = D(3,2) + YY
D(4,2) = D(4,2) + XYY
D(5,2) = D(5,2) + XXY
D(6,2) = D(6,2) + YYY
D(1,3) = D(1,3) + XY
D(2,3) = D(2,3) + XXY
D(3,3) = D(3,3) + XYY
D(4,3) = D(4,3) + XXYY
D(5,3) = D(5,3) + XXXY
D(6,3) = D(6,3) + XYYY
D(1,4) = D(1,4) + XX
D(2,4) = D(2,4) + XXX
D(3,4) = D(3,4) + XXY
D(4,4) = D(4,4) + XXXY
D(5,4) = D(5,4) + XXXX
D(6,4) = D(6,4) + XXYY
D(1,5) = D(1,5) + YY
D(2,5) = D(2,5) + XYY
D(3,5) = D(3,5) + YYY
D(4,5) = D(4,5) + XYYY
D(5,5) = D(5,5) + XXYY
D(6,5) = D(6,5) + YYYY
D(1,6) = D(1,6) + 1
D(2,6) = D(2,6) + X(L)
D(3,6) = D(3,6) + Y(L)
```

```
      D(4,6) = D(4,6) + XY
      D(5,6) = D(5,6) + XX
      D(6,6) = D(6,6) + YY
      D(1,7) = D(1,7) + V(L)
      D(2,7) = D(2,7) + VX
      D(3,7) = D(3,7) + VY
      D(4,7) = D(4,7) + VXY
      D(5,7) = D(5,7) + VXX
      D(6,7) = D(6,7) + VYY
      B(1)=B(1)+U(L)
      B(2)=B(2)+UX
      B(3)=B(3)+UY
      B(4)=B(4)+UXY
      B(5)=B(5)+UXX
      B(6)=B(6)+UYY
90    CONTINUE
      DO 377 I= 1,6
      DO 377 J= 1,6
377    DD(I,J)= D(I,J)
      L=6
      CALL SES
      VGPQ(KGP)= UORV
      DO91 I= 1,6
      D(I,7)= B(I)
91    CONTINUE
      DO 378 I= 1,6
      DO 378 J= 1,6
378    D(I,J)= DD(I,J)
      CALL SES
      UGPQ(KGP)= UORV
5004  CONTINUE
5010  CONTINUE
      L=LS
 92   CONTINUE
      DO 200 I = 1,201
      RU5Q(I) = UGPQ(I)
      RV5Q(I) = VGPQ(I)
 200  CONTINUE
      GO TO 551
 551  CONTINUE
93    CONTINUE
26    CONTINUE
      IF(SENSE SWITCH 2)6010,6015
 6010 WRITE OUTPUT TAPE 6,6011,(RU5Q(I),RV5Q(I),I=1,201)
 6011 FORMAT(10F11.2)
 6015  DO 193 IFT= 1,1
      DO 216 I= 1,201
      UGPP(I)= 999.99
      VGPP(I)= 999.99
216   CONTINUE
       DO192 KGP= 1,201
      Q1T=0.
      Q1=0.
      Q2T=0.
      Q2=0.
      Q2T=0.
```

```
      Q3=0.
      Q4T=0.
      Q4=0.
      L=0
      IF(MFP)8005,8000,8005
 8005 J=5
      DO 8010 I=1,201
      IF(P(J)-999.99)8015,8010,8015
 8015 IF(3.0-ABSF(GLAT(KGP)-GLAT(I)))8010,8020,8020
 8020 CONTINUE
      IF(3.0-ABSF(GLON(KGP)-GLON(I)))8010,8025,8025
 8025 CONTINUE
      U(L+1)=P(J)
      V(L+1)=P(J+1)
      L=L+1
      ISS(L)=I
      X(L)=(GLON(I)-GLON(KGP))
      Y(L)=GLAT(I)-GLAT(KGP)
 8010 J=J+2
 8000 DO 5100 I= 1,LF
      ISN= JS(I)
      IF( PLATB - ABSF(GLAT(KGP) - SLA(ISN))) 5100,5101,5101
5101  CONTINUE
      IF( PLONB - ABSF(GLON(KGP) - SLN(ISN))) 5100,5102,5102
5102  CONTINUE
      IF(100.-ABSF(U50(I))) 5100,5100,94
94    IF(100.-ABSF(V50(I))) 5100,5100,852
852    CONTINUE
      U(L+1) = U50(I)
      V(L+1) = V50(I)
      GO TO 85
85     CONTINUE
      L=L+1
      ISS(L)= JS(I)
      X(L)=(SLN(ISN)-GLON(KGP))
      Y(L)= SLA(ISN)-GLAT(KGP)
5100  CONTINUE
      DO 5105 I= 1,L
      IF(X(I)) 5106,5107,5107
5106  CONTINUE
      IF(Y(I)) 5108,5109,5109
5108  CONTINUE
      Q3T=1.
      Q3 =1.+Q3
      GO TO 5105
5109  CONTINUE
      Q2T=1.
      Q2 =1.+Q2
      GO TO 5105
5107  CONTINUE
      IF(Y(I)) 5111,5112,5112
5111  CONTINUE
      Q4T=1.
      Q4 =1.+Q4
      GOTO 5105
5112  CONTINUE
```

```
      Q1T=1.
      Q1=1.+Q1
5105  CONTINUE
      IN=L
      SQ= Q1T+Q2T+Q3T+Q4T
      IF(NSPB-L) 5103,5103,5104
5103  CONTINUE
      IF(SQ-3.) 5110,5113,5113
5113  CONTINUE
      IF(SENSE SWITCH 2)6020,6025
 6020 WRITE OUTPUT TAPE 6,6001,KGP,(U(I),V(I),X(I),Y(I),I=1,L)
 6025  SVX  = 0.
      SX   =  0.
      SY   =  0.
      SYY  =  0.
      SXY  =  0.
      SXX  =  0.
      SV   =  0.
      SU   =  0.
      SVY  =  0.
      SUX  =  0.
      SUY  =  0.
      DO 11 N=1,IN
      SX= SX + X(N)
      SY= SY + Y(N)
      SV = SV + V(N.
      SU = SU + U(N)
      SXY= SXY + X(N)*Y(N)
      SXX= SXX + X(N)*X(N)
      SYY= SYY + Y(N)*Y(N)
      SVY = SVY + V(N)*Y(N)
      SVX = SVX + V(N)*X(N)
      SUX = SUX + U(N)*X(N)
      SUY = SUY + U(N)*Y(N)
11    CONTINUE
       IF(SX+SY) 4001,4002,4001
4002  CONTINUE
       XIN = IN
      VGPP(KGP) = SV/XIN
       UGPP(KGP) = SU/XIN
       GO TO 5110
4001   CONTINUE
      FIN = IN
      AP = SXY * SX - SXX * SY
      BP = SYY * SX - SY  * SXY
      UGPP(KGP)=(AP*(SU*SXY-SUY*SX) -BP*(SU*SXX-SUX*SX)) / (BP*(SX*SX-
     1               FIN *SXX) - AP*(SX*SY - FIN*SXY))
      VGPP(KGP)=(AP*(SV*SXY-SVY*SX) -BP*(SV*SXX-SVX*SX)) / (BP*(SX*SX-
     1               FIN *SXX) - AP*(SX*SY - FIN*SXY))
5110    CONTINUE
5104    CONTINUE
       L=IN
 192  CONTINUE
      DO 554 I = 1,201
      RU5P(I) = UGPP(I)
      RV5P(I) = VGPP(I)
```

```
 554  CONTINUE
      GO TO 555
 555  CONTINUE
193    CONTINUE
      IF(SENSE SWITCH 2)6030,6035
 6030 WRITE OUTPUT TAPE 6,6011,(RU5P(I),RV5P(I),I=1,201)
 6035 RETURN
      END
```

```
      SUBROUTINE SES
      COMMON U
      EQUIVALENCE (U(2465),D(0044),L(0001),UORV(0002))
      DIMENSION D(6,7)
      M=0
      II=L+1
      DO100 K=2,II
      M=M+1
      DO100 J=K,II
      D(M,J)=D(M,J)/D(M,M)
      IF(L-K)103,104,104
104   CONTINUE
      DO101 I=K,L
      D(I,J)=D(I,J)-D(I,M)*D(M,J)
101   CONTINUE
103   CONTINUE
100   CONTINUE
      UORV=D(L,II)
      RETURN
      END
```

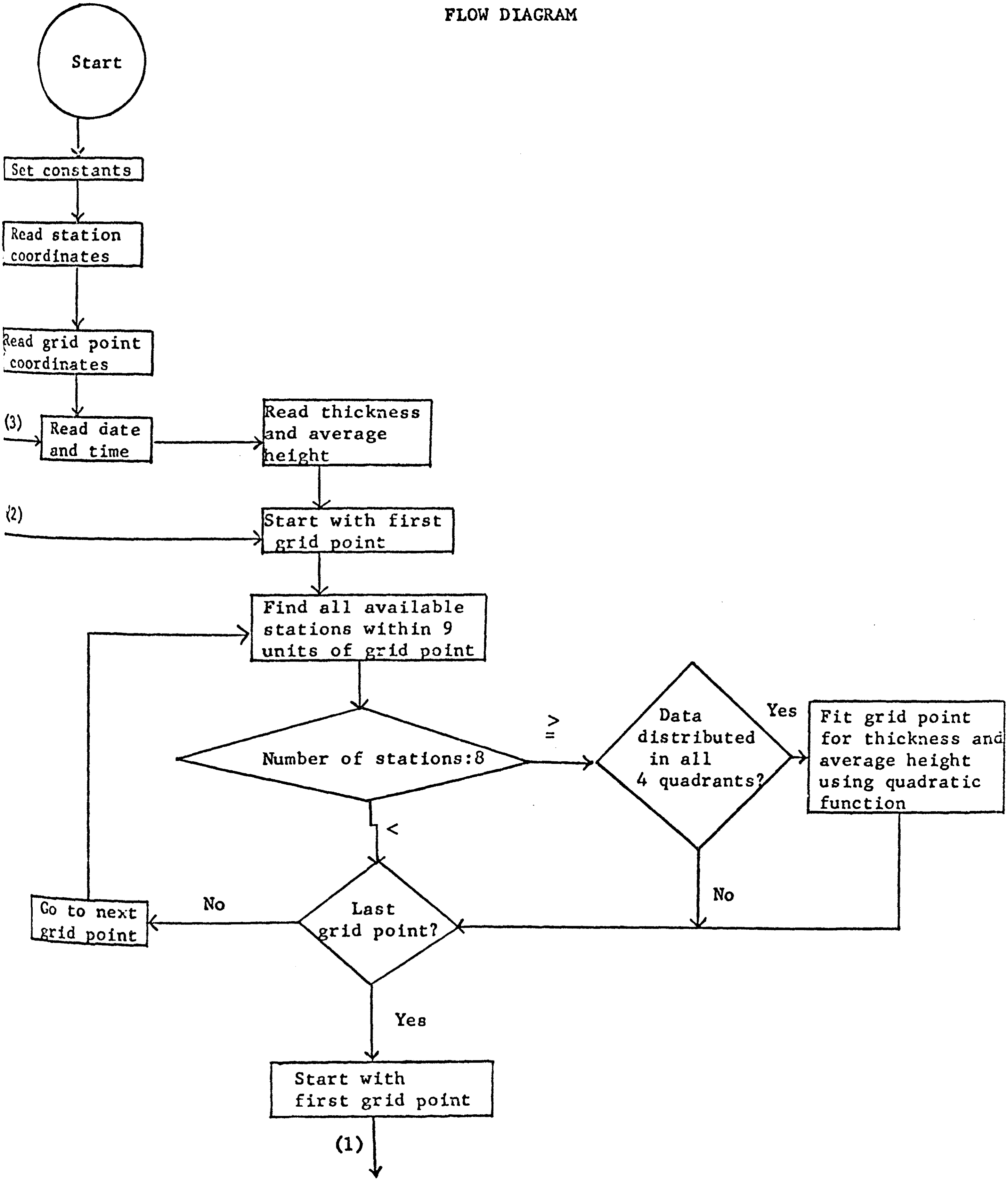
```
      SUBROUTINE P4
      COMMON O
      EQUIVALENCE(O(1617), RU5Q(809),  RV5Q(608),
     A           RU5P(407),  RV5P(206),
     C                                  P(1617),NVEL(1211),NANG(1010)
     D       ,   RTD(   5),  RD5Q(   4),  RT5Q(   3)
     E       ),(O(2421),CK(6)),(O(2878),MPT(1),MFP(2)),(O(2879),KA(1))
      DIMENSION              RU5Q(201),  RV5Q(201)
     A       ,  RU5P(201),   RV5P(201),
     C                                  P(0406),  NVEL(201),  NANG(201)
 460  DO 620 JK=1,201
      IF(RU5Q(JK)-CK)480,470,470
 470  RU5Q(JK)=RU5P(JK)
 480  IF(RV5Q(JK)-CK)500,490,490
 490  RV5Q(JK)=RV5P(JK)
 500  CONTINUE
 620  CONTINUE
      P(1)=RD5Q
      P(2)=RT5Q
      NP=4
      DO 630 JL=1,201
      NP=NP+1
      P(NP)=RU5Q(JL)
      NP=NP+1
 630  P(NP)=RV5Q(JL)
      IF(SENSE SWITCH 2)730,731
 730  WRITE OUTPUT TAPE 6,732,(P(JV),JV=_,406)
 732  FORMAT(A6,I6   ,2F8.2/(8F12.2))
 731  NV=0
      DO 1250 JX=5,405,2
      KX=JX+1
      NV=NV+1
      IF(P(JX)-999.99)751,755,755
 755  NVEL(NV)=99
      NANG(NV)=999
      GO TO 1250
 751  NVEL(NV) = SQRTF(P(JX)**2 + P(KX)**2) + .5
      IF(P(JX))790,750,790
 750  IF(P(KX))780,770,760
 760  NANG(NV)=180
      GO TO 1250
 770  NANG(NV)=0
      GO TO 1250
 780  NANG(NV)=360
      GO TO 1250
 790  IF(P(KX))830,800,830
 800  IF(P(JX))810,770,820
 810  NANG(NV)=90
      GO TO 1250
 820  NANG(NV)=270
      GO TO 1250
 830  CONTINUE
      NANG(NV) = ATANF(ABSF(P(JX)/P(KX)))*RTD + .5
      IF(P(JX)) 850,850,840
 850  IF(P(KX)) 1250,1250,870
 870  NANG(NV)=180-NANG(NV)
```

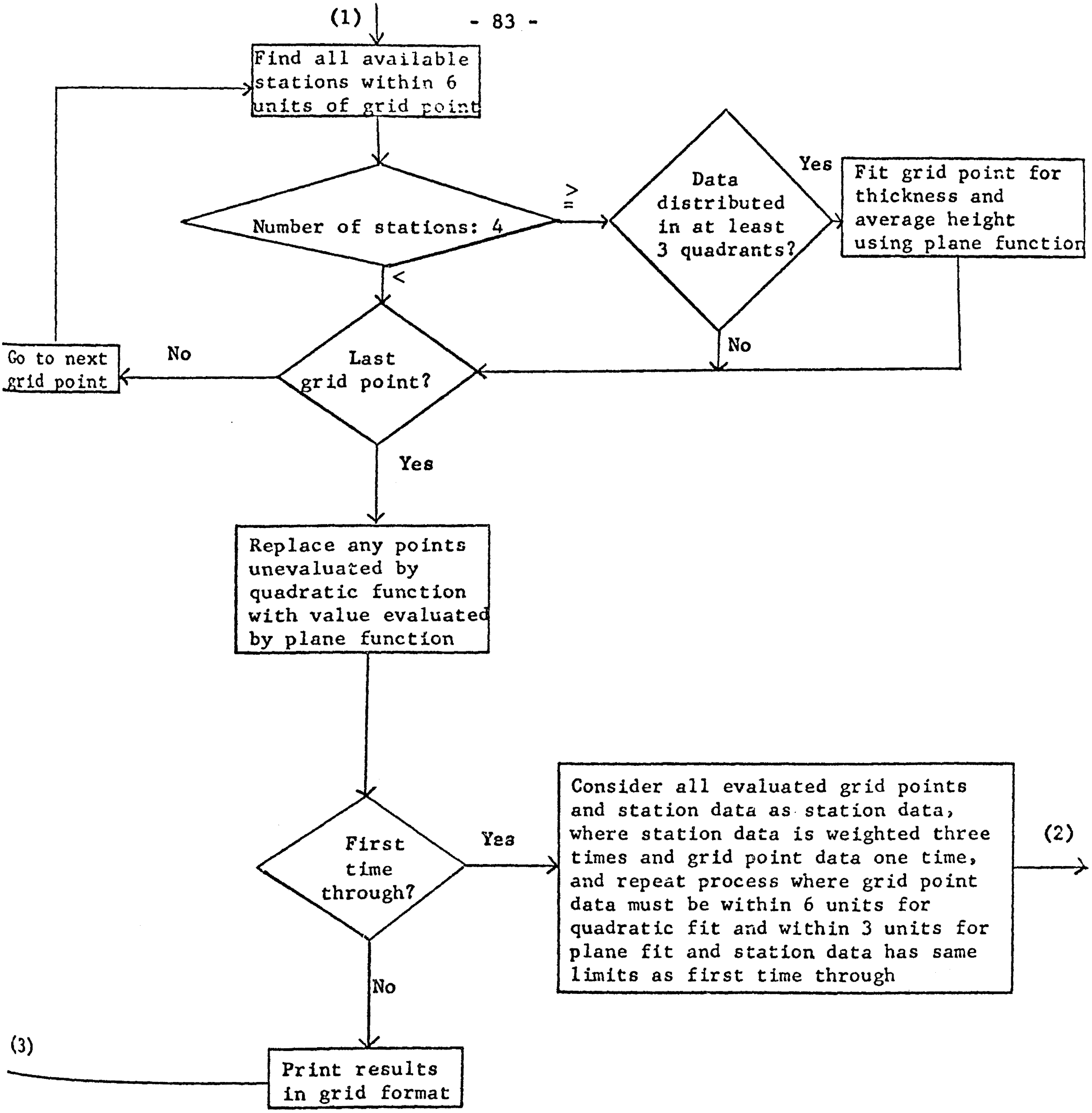
```
      GO TO 1250
840   IF(P(KX)) 880,880,890
880   NANG(NV)=360-NANG(NV)
      GO TO 1250
890   NANG(NV) = NANG(NV) + 180
1250  CONTINUE
      IF(MFP)2002,2001,2002
2002  CONTINUE
      WRITEOUTPUTTAPE MPT,3,KA,(P(MA),MA=1,2)
    3 FORMAT(1H19X,3HMAPI6,9X,4HDATEA9,9X,4HTIMEI6////)
      WRITE OUTPUT TAPE MPT,4,(NANG(MB),NVEL(MB),MB=1,3)
4     FORMAT(17X,3(I4,1H/I3,5X)///)
      MB1=7
      MB2=15
2004  WRITE OUTPUT TAPE MPT,5,(NANG(MB),NVEL(MB),MB=MB1,MB2)
5     FORMAT(4X,8(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+18
      MB2=MB2+18
      IF(MB2-177)2004,2004,2005
2005  WRITE OUTPUT TAPE MPT,6,(NANG(MB),NVEL(MB),MB=187,189)
6     FORMAT(30X,30X,22X,2(I4,1H/I3,5X),I4,1H/I3///)
      WRITE OUTPUT TAPE MPT,7,NANG(199),NVEL(199)
7     FORMAT(30X,30X,30X,18X,I4,1H/I3)
      WRITE OUTPUT TAPE MPT,2,KA
2     FORMAT(1H1,9X,I6)
      WRITE OUTPUT TAPE MPT,8,(NANG(MB),NVEL(MB),MB=4,6)
8     FORMAT(     ///  30X,30X,22X,2(I4,1H/I3,5X),I4,1H/I3///)
      MB1=16
      MB2=24
2006  WRITE OUTPUT TAPE MPT,5,(NANG(MB),NVEL(MB),MB=MB1,MB2)
      MB1=MB1+18
      MB2=MB2+18
      IF(MB2-186)2006,2006,2007
2007  WRITE OUTPUT TAPE MPT,5,(NANG(MB),NVEL(MB),MB=190,198)
      WRITE OUTPUT TAPE MPT,9,(NANG(MB),NVEL(MB),MB=200,201)
9     FORMAT(4X,2(I4,1H/I3,5X))
      WRITE OUTPUT TAPE 7,3000,KA,(P(MA),MA=1,2)
3000  FORMAT(I4,A6,I3)
      WRITE OUTPUT TAPE 7,3005,(NANG(MB),NVEL(MB),MB=1,201)
3005  FORMAT(I4,I3,I4,I3,I4,I3,I4,I3,I4,I3,I4,I3,I4,I3,I4,I3,I4,I3,I4,I3
     1)
      GO TO 2003
2001  MFP=1
      IF(SENSE SWITCH 3)2002,2003
2003  RETURN
      END
```

```
      SUBROUTINE P5
      COMMON O
      EQUIVALENCE (O(2421),ISN(2),IPT(1),SH(3),IT(4),RAD(5),CK(6))
     A,(O(2474),QLATB(1),QLONB(2),PLATB(3),PLONB(4),NSQB(5),NSPB(6)
     B,A00(7),SDATE(8),STIME(9))
     D,(O(1915),SN( 300),SLA( 200),SLN( 100))
     E,                   (O(1613),RTD(1)),(O(2876),GLON(201),GLAT(402))
      DIMENSION SN(100),SLA(100),SLN(100),GLON(201),GLAT(201)
      SH=5H99999
      QLATB = 9.0
      QLONB = 9.0
      PLATB = 6.0
      PLONB = 6.0
      NSQB  = 8
      NSPB  = 4
      A00   = 20000.
      CK = 999.99
      RAD=.01745329
      RTD = 57.29578
      IT=1
      ISN=0
1     CONTINUE
      READ INPUT TAPE IPT,2,     S,X,Y
2     FORMAT(     1A5,6X,F5.2,2X,F5.2)
      IF(S-SH ) 3,4,3
3     CONTINUE
      ISN=ISN+1
      SN(ISN)=S
      SLA(ISN)=Y
      SLN(ISN)=X
      GOTO1
4     CONTINUE
      DO 2002 I = 1,201
 2002 READ INPUT TAPE IPT, 2003,(K),GLAT(K),GLON(K)
 2003 FORMAT(3X,I3,2F7.0)
       IF(SENSE SWITCH 2)3005,3000
 3005 WRITE OUTPUT TAPE 6,3006,(GLON(I),GLAT(I),I=1,201 ),(SN(I),SLA(I),
     1SLN(I),I=1,ISN)
 3006 FORMAT(40(10F7.1/),2F7.1//(1X,A5,2F10.2,1X,A5,2F10.2,1X,A5,2F10.2)
     1)
 3000 RETURN
      END
```

Program "GRIDHT" is used for the horizontal analysis of thickness and average height. The main program and subroutines WHIT, SES, AND P5 are the same as listed for program "GRID".

FLOW DIAGRAM





SYMBOL DEFINITIONS

All symbols are the same as those used in the corresponding subroutines or the main program for "GRID" except the symbols used as wind speed or U component are used for thickness of the layer of maximum wind and those used as wind direction or V component are used for average height of the layer of maximum wind in "GRIDHT".

COMPUTER TIME

Objective analyses of LMW heights and thicknesses consume approximately 25 seconds of IBM 7090 computer time per map for both parameters.

```
      SUBROUTINE P1
      COMMON O
      EQUIVALENCE(NS,IS)
      EQUIVALENCE(O(2880),LF(1))
      EQUIVALENCE(O(2878),MPT(1))
      EQUIVALENCE(O(2415),   SN( 800),   SLA( 700),   SLN( 600)
     A        ,              V50( 500),  U50( 400),  A50H( 300)
     B        ,   IOA( 200),   JS( 100),   NSN( 800))
     C        ,   (IS,S),(ISH,SH),(O(2421),ISN(2),IPT(1),SH(3),IT(4)
     D        ,   RAD(5))
      DIMENSION              SN(0100),   SLA(0100), SLN(0100)
     A        ,              V50(0100),  U50(0100), A50H(0100)
     B        ,   IOA(0100),   JS(0100),   NSN(0100)
      IO=0
      LF=0
   10 CONTINUE
      READ INPUT TAPE IPT, 7,S,D1,D2,I50VV,I50DD
    7 FORMAT(1X,1A5,2(1X,1A4),27X,2I6)
      IF(IS-ISH) 9,8,9
    9 CONTINUE
      DO11 I=1,ISN
      IF(NS-NSN(I)) 11,12,11
   11 CONTINUE
      GO TO 10
   12 CONTINUE
      JSN=I
      IO=IO+1
      LF=LF+1
      A50VV = FLOATF(I50VV)
      A50DD = FLOATF(I50DD)
      V50(LF) =  A50VV
      U50(LF) =  A50DD
      JS(LF)=JSN
      IOA(LF) = IO
      GOTO10
    8 CONTINUE
      IF(SENSE SWITCH 2)100,105
  100 WRITE OUTPUT TAPE 6,106,(V50(I),U50(I),        JS(I),IOA(I),I=1,LF
     1)
  106 FORMAT(2F12.2,F15.2,2I5)
  105 RETURN
      END
```

```
      SUBROUTINE P3
      COMMON O
      EQUIVALENCE(O(2880),LF(1))
      EQUIVALENCE(O(2878),MPT(1))
      EQUIVALENCE(O(1617), RU5Q(809),   RV5Q(608)
     A       ,   RU5P(407),  RV5P(206),
     C                                    P(1617),NVEL(1211),NANG(1010)
     D       ,    RTD(   5),  RD5Q(   4),  RT5Q(   3)
     E      ),(O(2416),CK(6))
     F,(O(2465),D(44),L(1),UORV(2))
     G,(O(2474),QLATB(1),QLONB(2),PLATE(3),PLONB(4),NSQB(5),NSPB(6))
      DIMENSION               RU5Q(201),   RV5Q(201)
     A       ,   RU5P(201),   RV5P(201),
     C                                    P(0406),   NVEL(201),   NANG(201,
     D,                  U(100),B(6),D(6,7),DD(6,6),UGPP(201),VGPP(201)
     E,UGPQ(201),VGPQ(201)
      EQUIVALENCE(O(2415),   SN( 800),    SLA( 700),   SLN( 600)
     A       ,            V50( 500),    U50( 400),  A50H( 300)
     B       ,    IOA( 200),   JS( 100),   NSN(800))
     C,(IS,S),(ISH,SH),(O(2421),          IPT(1),SH(3),IT(4)
     D,RAD(5))
     E,(O(2876),          GLON(201),GLAT(402)),(O(2877),MFP(1))
     F                         ,(O(406),P(406))
      DIMENSION               SN(0100),   SLA(0100),  SLN(0100)
     A       ,            V50(0100),    U50(0100),  A50H(0100)
     B,IOA(0100),JS(0100),NSN(0100),                     V(100),
     C          X(100),Y(100),ISS(100)
     D,GLAT(201),GLON(201)
      DO 93 IFT=1,1
      DO 213 I= 1,201
      UGPQ(I)= 999.99
      VGPQ(I)= 999.99
213   CONTINUE
      DO 92 KGP=1,201
      Q1T=0.
      Q1=0.
      Q2T=0.
      Q2=0.
      Q3T=0.
      Q3=0.
      Q4T=0.
      Q4=0.
      L=0
      IF(MFP)7005,7000,7005
 7005 J=KGP*2+3
      IF(P(J)-999.99)9005,9000,9005
 9005 UGPQ(KGP)=P(J)
      VGPQ(KGP)=P(J+1)
      GO TO 92
 9000 J=5
      DO 7010 I=1,201
      IF(P(J)-999.99)7015,7010,7015
 7015 IF(6.0-ABSF(GLAT(KGP)-GLAT(I)))7010,7020,7020
 7020 CONTINUE
      IF(6.0-ABSF(GLON(KGP)-GLON(I)))7010,7025,7025
 7025 CONTINUE
```

```
      U(L+1)=P(J)
      V(L+1)=P(J+1)
      L=L+1
      ISS(L)=I
      X(L)=(GLON(I)-GLON(KGP))
      Y(L)=GLAT(I)-GLAT(KGP)
 7010 J=J+2
 7000 DO 5000 I= 1,LF
      IF(MFP)9010,9015,9010
 9010 JJ=1
 9015 ISN= JS(I)
      IF( QLATB - ABSF(GLAT(KGP) - SLA(ISN)))  5000,5001,5001
5001  CONTINUE
      IF( QLONB - ABSF(GLON(KGP) - SLN(ISN)))  5000,5002,5002
5002  CONTINUE
      IF(100.-ABSF(U50(I))) 73,5000,5000
73    IF(100.-ABSF(V50(I))) 652,5000,5000
652   CONTINUE
 9025 U(L+1)=U50(I)
      V(L+1)=V50(I)
      GO TO 65
65    CONTINUE
      L=L+1
      ISS(L)= JS(I)
      X(L)=(SLN(ISN)-GLON(KGP))
      Y(L)= SLA(ISN)-GLAT(KGP)
      IF(MFP)9020,5000,9020
 9020 JJ=JJ+1
      IF(JJ-4)9025,9025,5000
5000  CONTINUE
      DO 5005 I= 1,L
      IF(X(I)) 5006,5007,5007
5006  CONTINUE
      IF(Y(I)) 5008,5009,5009
5008  CONTINUE
      Q3T=1.
      Q3  =1.+Q3
      GO TO 5005
5009  CONTINUE
      Q2T=1.
      Q2  =1.+Q2
      GO TO 5005
5007  CONTINUE
      IF(Y(I)) 5011,5012,5012
5011  CONTINUE
      Q4T=1.
      Q4  =1.+Q4
      GOTO 5005
5012  CONTINUE
      Q1T=1.
      Q1=1.+Q1
5005  CONTINUE
      LS=L
      SQ= Q1T+Q2T+Q3T+Q4T
      IF(NSQB-L) 5003,5003,5004
5003  CONTINUE
```

```
      IF(SQ-4.)5010,5013,5013
5013  CONTINUE
      IF(SENSE SWITCH 2)6000,6005
 6000 WRITE OUTPUT TAPE 6,6001,KGP,(U(I),V(I),X(I),Y(I),I=1,L)
 6001 FORMAT(I5/(4F15.2))
 6005 DO 5  I =1,6
      B(I)=0.
      DO 5  J =1,7
      D(I,J)=0.
5     CONTINUE
      DO 90 L=1,LS
      XY   = X(L) * Y(L)
      XX   = X(L) * X(L)
      YY   = Y(L) * Y(L)
      XXY  = X(L) * X(L) * Y(L)
      XXX  = X(L) * X(L) * X(L)
      XYY  = X(L) * Y(L) * Y(L)
      YYY  = Y(L) * Y(L) * Y(L)
      XXYY = X(L) * X(L) * Y(L) * Y(L)
      XXXY = X(L) * X(L) * X(L) * Y(L)
      XYYY = X(L) * Y(L) * Y(L) * Y(L)
      XXXX = X(L) * X(L) * X(L) * X(L)
      YYYY = Y(L) * Y(L) * Y(L) * Y(L)
      UX   = U(L) * X(L)
      UY   = U(L) * Y(L)
      UXY  = U(L) * X(L) * Y(L)
      UXX  = U(L) * X(L) * X(L)
      UYY  = U(L) * Y(L) * Y(L)
      VX   = V(L) * X(L)
      VY   = V(L) * Y(L)
      VXY  = V(L) * X(L) * Y(L)
      VXX  = V(L) * X(L) * X(L)
      VYY  = V(L) * Y(L) * Y(L)
      D(1,1) = D(1,1) + X(L)
      D(2,1) = D(2,1) + XX
      D(3,1) = D(3,1) + XY
      D(4,1) = D(4,1) + XXY
      D(5,1) = D(5,1) + XXX
      D(6,1) = D(6,1) + XYY
      D(1,2) = D(1,2) + Y(L)
      D(2,2) = D(2,2) + XY
      D(3,2) = D(3,2) + YY
      D(4,2) = D(4,2) + XYY
      D(5,2) = D(5,2) + XXY
      D(6,2) = D(6,2) + YYY
      D(1,3) = D(1,3) + XY
      D(2,3) = D(2,3) + XXY
      D(3,3) = D(3,3) + XYY
      D(4,3) = D(4,3) + XXYY
      D(5,3) = D(5,3) + XXXY
      D(6,3) = D(6,3) + XYYY
      D(1,4) = D(1,4) + XX
      D(2,4) = D(2,4) + XXX
      D(3,4) = D(3,4) + XXY
      D(4,4) = D(4,4) + XXXY
      D(5,4) = D(5,4) + XXXX
```

```
      D(6,4) = D(6,4) + XXYY
      D(1,5) = D(1,5) + YY
      D(2,5) = D(2,5) + XYY
      D(3,5) = D(3,5) + YYY
      D(4,5) = D(4,5) + XYYY
      D(5,5) = D(5,5) + XXYY
      D(6,5) = D(6,5) + YYYY
      D(1,6) = D(1,6) + 1.
      D(2,6) = D(2,6) + X(L)
      D(3,6) = D(3,6) + Y(L)
      D(4,6) = D(4,6) + XY
      D(5,6) = D(5,6) + XX
      D(6,6) = D(6,6) + YY
      D(1,7) = D(1,7) + V(L)
      D(2,7) = D(2,7) + VX
      D(3,7) = D(3,7) + VY
      D(4,7) = D(4,7) + VXY
      D(5,7) = D(5,7) + VXX
      D(6,7) = D(6,7) + VYY
      B(1)=B(1)+U(L)
      B(2)=B(2)+UX
      B(3)=B(3)+UY
      B(4)=B(4)+UXY
      B(5)=B(5)+UXX
      B(6)=B(6)+UYY
90    CONTINUE
      DO 377 I= 1,6
      DO 377 J= 1,6
377    DD(I,J)= D(I,J)
      L=6
      CALL SES
      VGPQ(KGP)= UORV
      DO91 I= 1,6
      D(I,7)= B(I)
91    CONTINUE
      DO 378 I= 1,6
      DO 378 J= 1,6
378    D(I,J)= DD(I,J)
      CALL SES
      UGPQ(KGP)= UORV
5004  CONTINUE
5010  CONTINUE
      L=LS
 92   CONTINUE
      DO 200 I = 1,201
      RU5Q(I) = UGPQ(I)
      RV5Q(I) = VGPQ(I)
 200  CONTINUE
      GO TO 551
 551  CONTINUE
93    CONTINUE
26    CONTINUE
      IF(SENSE SWITCH 2)6010,6015
 6010 WRITE OUTPUT TAPE 6,6011,(RU5Q(I),RV5Q(I),I=1,201)
 6011 FORMAT(10F11.2)
 6015  DO 193 IFT= 1,1
```

```
      DO 216 I= 1,201
      UGPP(I)= 999.99
      VGPP(I)= 999.99
216   CONTINUE
       DO192 KGP= 1,201
      Q1T=0.
      Q1=0.
      Q2T=0.
      Q2=0.
      Q3T=0.
      Q3=0.
      Q4T=0.
      Q4=0.
      L=0
      IF(MFP)8005,8000,8005
 8005 J=KGP*2+3
      IF(P(J)-999.99)9035,9030,9035
 9035 UGPP(KGP)=P(J)
      VGPP(KGP)=P(J+1)
      GO TO 192
 9030 J=5
      DO 8010 I=1,201
      IF(P(J)-999.99)8015,8010,8015
 8015 IF(3.0-ABSF(GLAT(KGP)-GLAT(I)))8010,8020,8020
 8020 CONTINUE
      IF(3.0-ABSF(GLON(KGP)-GLON(I)))8010,8025,8025
 8025 CONTINUE
      U(L+1)=P(J)
      V(L+1)=P(J+1)
      L=L+1
      ISS(L)=I
      X(L)=(GLON(I)-GLON(KGP))
      Y(L)=GLAT(I)-GLAT(KGP)
 8010 J=J+2
 8000 DO 5100 I= 1,LF
      IF(MFP)9040,9045,9040
 9040 JJ=1
 9045 ISN= JS(I)
      IF( PLATB - ABSF(GLAT(KGP) - SLA(ISN))) 5100,5101,5101
5101  CONTINUE
      IF( PLONB - ABSF(GLON(KGP) - SLN(ISN))) 5100,5102,5102
5102  CONTINUE
      IF(100.-ABSF(U50(I))) 94,5100,5100
94    IF(100.-ABSF(V50(I))) 852,5100,5100
852    CONTINUE
 9051 U(L+1) = U50(I)
      V(L+1) = V50(I)
      GO TO 85
85     CONTINUE
      L=L+1
      ISS(L)= JS(I)
      X(L)=(SLN(ISN)-GLON(KGP))
      Y(L)= SLA(ISN)-GLAT(KGP)
      IF(MFP)9050,5100,9050
 9050 JJ=JJ+1
      IF(JJ-4)9055,9055,5100
```

```
5100  CONTINUE
      DO 5105 I= 1,L
      IF(X(I)) 5106,5107,5107
5106  CONTINUE
      IF(Y(I)) 5108,5109,5109
5108  CONTINUE
      Q3T=1.
      Q3 =1.+Q3
      GO TO 5105
5109  CONTINUE
      Q2T=1.
      Q2 =1.+Q2
      GO TO 5105
5107  CONTINUE
      IF(Y(I)) 5111,5112,5112
5111  CONTINUE
      Q4T=1.
      Q4 =1.+Q4
      GOTO 5105
5112  CONTINUE
      Q1T=1.
      Q1=1.+Q1
5105  CONTINUE
      IN=L
      SQ= Q1T+Q2T+Q3T+Q4T
      IF(NSPB-L) 5103,5103,5104
5103  CONTINUE
      IF(SQ-3.) 5110,5113,5113
5113  CONTINUE
      IF(SENSE SWITCH 2)6020,6025
 6020 WRITE OUTPUT TAPE 6,6001,KGP,(U(I),V(I),X(I),Y(I),I=1,L)
 6025  SVX  = 0.
      SX   =  0.
      SY   =  0.
      SYY  =  0.
      SXY  =  0.
      SXX  =  0.
      SV   =  0.
      SU   =  0.
      SVY  =  0.
      SUX  =  0.
      SUY  =  0.
      DO 11 N=1,IN
      SX= SX + X(N)
      SY= SY + Y(N)
      SV = SV + V(N)
      SU = SU + U(N)
      SXY= SXY + X(N)*Y(N)
      SXX= SXX + X(N)*X(N)
      SYY= SYY + Y(N)*Y(N)
      SVY = SVY + V(N)*Y(N)
      SVX = SVX + V(N)*X(N)
      SUX = SUX + U(N)*X(N)
      SUY = SUY + U(N)*Y(N)
11    CONTINUE
       IF(SX+SY) 4001,4002,4001
```

```
4002  CONTINUE
       XIN = IN
      VGPP(KGP) = SV/XIN
       UGPP(KGP) = SU/XIN
       GO TO 5110
4001   CONTINUE
      FIN = IN
      AP = SXY * SX - SXX * SY
      BP = SYY * SX - SY  * SXY
      UGPP(KGP)=(AP*(SU*SXY-SUY*SX) -BP*(SU*SXX-SUX*SX)) / (BP*(SX*SX-
     1              FIN *SXX) - AP*(SX*SY - FIN*SXY))
      VGPP(KGP)=(AP*(SV*SXY-SVY*SX) -BP*(SV*SXX-SVX*SX)) / (BP*(SX*SX-
     1              FIN *SXX) - AP*(SX*SY - FIN*SXY))
5110    CONTINUE
5104    CONTINUE
       L=IN
 192  CONTINUE
      DO 554 I = 1,201
      RU5P(I) = UGPP(I)
      RV5P(I) = VGPP(I)
 554  CONTINUE
      GO TO 555
 555  CONTINUE
193    CONTINUE
      IF(SENSE SWITCH 2)6030,6035
 6030 WRITE OUTPUT TAPE 6,6011,(RU5P(I),RV5P(I),I=1,201)
 6035 RETURN
      END
```

```
      SUBROUTINE P4
      COMMON O
      EQUIVALENCE(O(1617), RU5Q(809),  RV5Q(608),
     A          RU5P(407),  RV5P(206),
     C                                 P(1617),NVEL(1211),NANG(1010)
     D       ,   RTD(  5),  RD5Q(  4),  RT5Q(  3)
     E      ),(O(2421),CK(6)),(O(2878),MPT(1),MFP(2)),(O(2879),KA(1))
      DIMENSION                RU5Q(201),  RV5Q(201)
     A       ,  RU5P(201),  RV5P(201),
     C                                 P(0406),  NVEL(201),  NANG(201)
  460 DO 620 JK=1,201
      IF(RU5Q(JK)-CK)480,470,470
  470 RU5Q(JK)=RU5P(JK)
  480 IF(RV5Q(JK)-CK)500,490,490
  490 RV5Q(JK)=RV5P(JK)
 500  CONTINUE
 620  CONTINUE
      P(1)=RD5Q
      P(2)=RT5Q
      NP=4
      DO 630 JL=1,201
      NP=NP+1
      P(NP)=RU5Q(JL)
      NP=NP+1
 630  P(NP)=RV5Q(JL)
      IF(SENSE SWITCH 2)730,731
 730  WRITE OUTPUT TAPE 6,732,(P(JV),JV=1,406)
 732  FORMAT(A6,I6   ,2F8.2/(8F12.2))
 731  NV=0
      DO 1250 JX=5,405,2
      KX=JX+1
      NV=NV+1
      IF(P(JX)-999.99)755,755,751
 755  NVEL(NV)=99
      NANG(NV)=999
      GO TO 1250
 751  NVEL(NV)=P(JX)
      NANG(NV)=P(KX)
 1250 CONTINUE
      IF(MFP)2002,2001,2002
 2002 CONTINUE
      MB3=0
 2060 WRITEOUTPUTTAPE MPT,3,KA,(P(MA),MA=1,2)
    3 FORMAT(1H19X,3HMAPI6,9X,4HDATEA9,9X,4HTIMEI6////)
      WRITE OUTPUT TAPE MPT,4,(NANG(MB)             ,MB=1,3)
 4    FORMAT(17X,3(2X,I6    ,5X)///)
      MB1=7
      MB2=15
 2004 WRITE OUTPUT TAPE MPT,5,(NANG(MB),             MB=MB1,MB2)
 5    FORMAT(4X,8(2X,I6    ,5X),2X,I6    ///)
      MB1=MB1+18
      MB2=MB2+18
      IF(MB2-177)2004,2004,2005
 2005 WRITE OUTPUT TAPE MPT,6,(NANG(MB),             MB=187,189)
 6    FORMAT(30X,30X,22X,2(2X,I6    ,5X),2X,I6    ///)
      WRITE OUTPUT TAPE MPT,7,NANG(199)
```

```
7     FORMAT(30X,30X,30X,18X,2X,I6    )
      WRITE OUTPUT TAPE MPT,2,KA
2     FORMAT(1H1,9X,I6)
      WRITE OUTPUT TAPE MPT,8,(NANG(MB),          MB=4,6)
8     FORMAT(     ///  30X,30X,22X,2(2X,I6    ,5X),2X,I6    ///)
      MB1=16
      MB2=24
2006  WRITE OUTPUT TAPE MPT,5,(NANG(MB),          MB=MB1,MB2)
      MB1=MB1+18
      MB2=MB2+18
      IF(MB2-186)2006,2006,2007
2007  WRITE OUTPUT TAPE MPT,5,(NANG(MB),          MB=190,198)
      WRITE OUTPUT TAPE MPT,9,(NANG(MB),          MB=200,201)
9     FORMAT(4X,2(2X,I6    ,5X))
      WRITE OUTPUT TAPE 7,3000,KA,(P(MA),MA=1,2)
3000  FORMAT(I4,A6,I3)
      WRITE OUTPUT TAPE 7,3005,(NANG(MB)          ,MB=1,201)
3005  FORMAT(12I6)
      IF(MB3)2050,2050,2003
2050  MB3=1
      DO 2055 MB=1,201
2055  NANG(MB)=NVEL(MB)
      GO TO 2060
2001  MFP=1
      IF(SENSE SWITCH 3)2002,2003
2003  RETURN
      END
```

SUBROUTINE F4

No new symbols are used

FUNCTION KPS

Call list:

1. K - subscript to be cycled

```
C   FCST
      COMMON O
      DIMENSION O(3000)
      EQUIVALENCE (O(2),MPT(1),IPT(2)),(O(1913),DD(603),VV(1206),IP4(134
     17),IP3(1488),IP2(1629),IP1(1770),IP(1911)),(O(1914),TIM),(O(2196),
     2FV(141),FD(282)),(O(2200),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,3),DD(201,3),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=12.0
      KL=1
      KK=2
      KR=3
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL,KK,KR,K,IK,(DD(I,K),VV(I,K),I=1,201)
 90   FORMAT(5I6/(10F10.0))
 85   IF(IK-3)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL,KK)
      CALL F3(1)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR),VV(1,KR))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR),VV(1,KR))
      CALL F3(3)
      KL=KPS(KL)
      KK=KPS(KK)
      KR=KPS(KR)
```

```
      K=KR
      GO TO 65
      END





      SUBROUTINE F1
      COMMON O
      EQUIVALENCE (O(707),IP4(141),IP3(282),IP2(423),IP1(564),IP(705),IP
     1T(707),MPT(706))
      DIMENSION IP(141),IP1(141),IP2(141),IP3(141),IP4(141)
      READ INPUT TAPE IPT,10,(IP(I),IP1(I),IP2(I),IP3(I),IP4(I),I=1,141)
10    FORMAT(5I5)
      IF(SENSE SWITCH 3)15,20
15    WRITE OUTPUT TAPE MPT,25,(IP(I),IP1(I),IP2(I),IP3(I),IP4(I),I=1,14
     11)
25    FORMAT(I10,4I5,I10,4I5)
20    RETURN
      END
```

```
      SUBROUTINE F2(K1,K2)
      COMMON O
      EQUIVALENCE (O(2),MPT(1),IPT(2)),(O(1913),DD(603),VV(1206),IP4(134
     17),IP3(1488),IP2(1629),IP1(1770),IP(1911)),(O(1914),TIM),(O(2196),
     2FV(141),FD(282))
      DIMENSION IP(141),IP1(141),IP2(141),IP3(141),IP4(141),DD(201,3),
     1VV(201,3),U(201,2),V(201,2),FD(141),FV(141)
      D=2.0*3.0
      RAD=0.01745329
      K=K1
      IK=1
25    DO 10 I=1,201
      IF(VV(I ,K)-99.0)40,35,40
35    U(I,IK)=999.0
      V(I,IK)=999.0
      GO TO 10
40    U(I,IK)=-VV(I ,K)*SINF(DD(I ,K)*RAD)
      V(I,IK)=-VV(I ,K)*COSF(DD(I ,K)*RAD)
10    CONTINUE
      IF(SENSE SWITCH 3)125,130
125   WRITE OUTPUT TAPE MPT,135,K,IK,(U(I,IK),V(I,IK),I=1,201)
135   FORMAT(2I6/(10F10.5))
130   IF(IK-2)20,15,15
20    K=K2
      IK=2
      GO TO 25
15    DO 30 I=1,141
      II=IP(I)
      I1=IP1(I)
      I2=IP2(I)
      I3=IP3(I)
      I4=IP4(I)
      IF(U(II,1)-999.0)45,75,75
45    IF(U(II,2)-999.0)50,75,75
50    IF(U(I1,2)-999.0)55,75,75
55    IF(U(I2,2)-999.0)60,75,75
60    IF(U(I3,2)-999.0)65,75,75
65    IF(U(I4,2)-999.0)70,75,75
75    FD(I)=999.0
      FV(I)=99.0
      GO TO 30
70    DUDX=(U(I3,2)-U(I1,2))/D
      DUDY=(U(I4,2)-U(I2,2))/D
      DVDX=(V(I3,2)-V(I1,2))/D
      DVDY=(V(I4,2)-V(I2,2))/D
      DVDT=(V(II,2)-V(II,1))/TIM
      DUDT=(U(II,2)-U(II,1))/TIM
      DE=DUDX*DVDY-DUDY*DVDX
      CX=(DUDY*DVDT-DVDY*DUDT)/DE
      CY=(DVDX*DUDT-DUDX*DVDT)/DE
      IF(SENSE SWITCH 2)140,145
140   WRITE OUTPUT TAPE MPT,150,I,II,I1,I2,I3,I4,DUDX,DUDY,DVDX
     1T,DUDT,DE,CX,CY
150   FORMAT(6I6/9F10.5)
145   DUDT=(-CX*DUDX-CY*DUDY)*TIM
      DVDT=(-CX*DVDX-CY*DVDY)*TIM
```

```
      UF=U(II,2)+DUDT
      VF=V(II,2)+DVDT
      IF(SENSE SWITCH 2)155,160
155   WRITE OUTPUT TAPE MPT,165,DUDT,DVDT,UF,VF
165   FORMAT(4F10.5)
160   FV(I)=SQRTF(UF*UF+VF*VF)
      IF(VF)80,85,80
85    IF(UF)90,95,100
95    FD(I)=0.0
      GO TO 30
90    FD(I)=90.0
      GO TO 30
100   FD(I)=270.0
      GO TO 30
80    FD(I)=ATANF(UF/VF)/RAD
      IF(UF)110,105,105
110   IF(VF)30,115,115
115   FD(I)=FD(I)+180.0
      GO TO 30
105   IF(VF)120,115,115
120   FD(I)=FD(I)+360.0
30    CONTINUE
      IF(SENSE SWITCH 2)170,175
170   WRITE OUTPUT TAPE MPT,180,(FD(I),FV(I),I=1,141)
180   FORMAT(10F10.2)
175   RETURN
      END
```

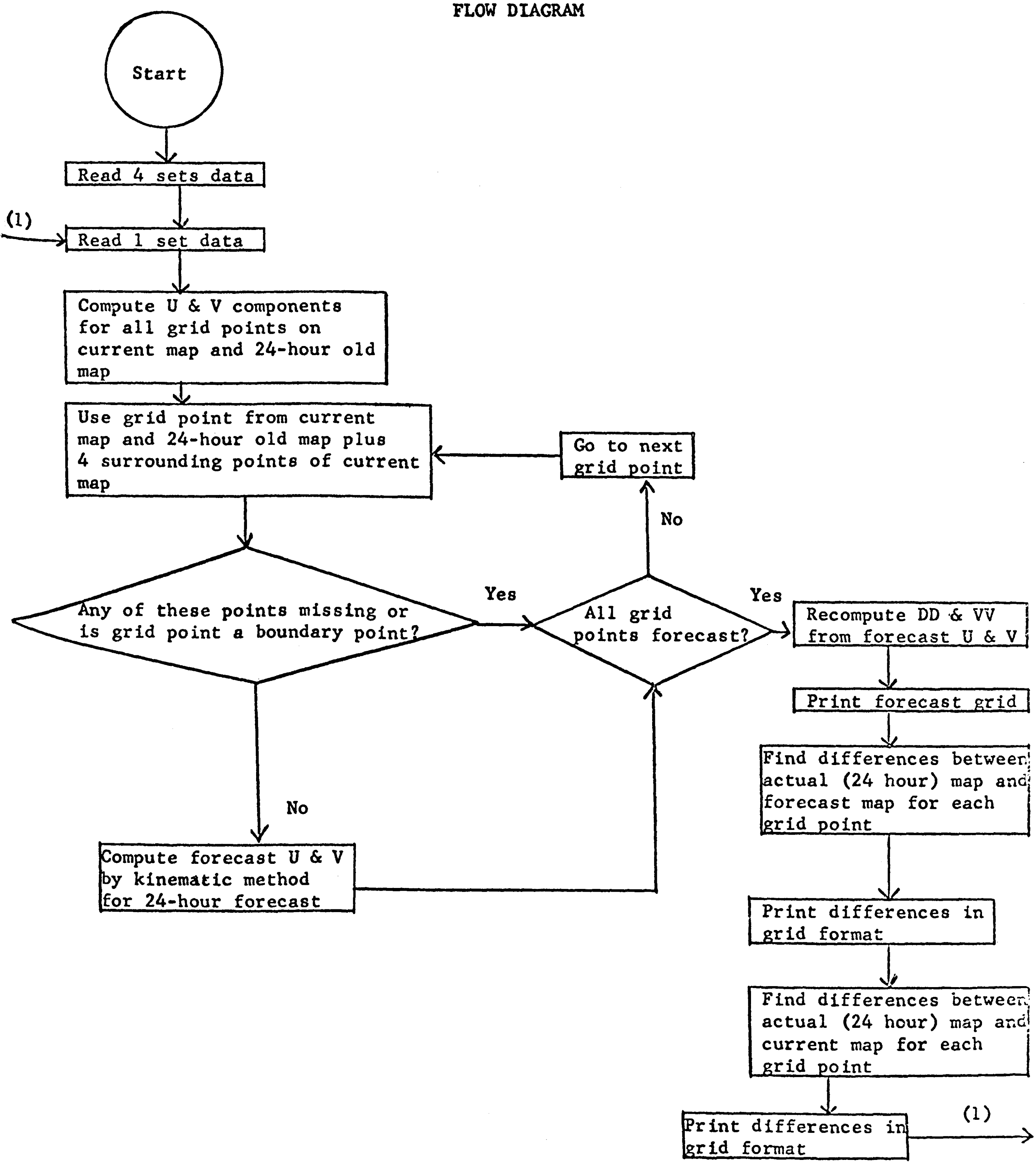
```
      SUBROUTINE F3(I)
      COMMON O
      EQUIVALENCE(O(2196),FV(141),FD(282)),(O(2200),TIME(2),DATE(3),KA(1
     1)),(O(2),MPT)
      DIMENSION FD(141),FV(141),ND(141),NV(141)
      IF(I-2)70,75,80
70    WRITE OUTPUT TAPE MPT,10,KA,DATE,TIME
10    FORMAT(1H1I4,A8,A3,17H 12 HOUR FORECAST///////)
      GO TO 85
75    WRITE OUTPUT TAPE MPT,11,KA,DATE,TIME
11    FORMAT(1H1I4,A8,A3,43H DIFFERENCE BETWEEN ACTUAL MAP AND FORECAST/
     1///////)
      GO TO 85
80    WRITE OUTPUT TAPE MPT,12,KA,DATE,TIME
12    FORMAT(1H1I4,A8,A3,26H DIFFERENCE BY PERSISTENCE///////)
85    DO 90 I=1,141
      ND(I)=FD(I)
90    NV(I)=FV(I)
      WRITE OUTPUT TAPE MPT,15, ND(1),NV(1)
15    FORMAT(30X,I4,1H/I3///)
      MB1=3
      MB2=10
25    WRITE OUTPUT TAPE MPT,20,(ND(I),NV(I),I=MB1,MB2)
20    FORMAT(17X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-122)25,25,30
30    WRITE OUTPUT TAPE MPT,35,(ND(I),NV(I),I=131,132)
35    FORMAT(35X,35X,25X,I4,1H/I3,5X,I4,1H/I3)
      WRITE OUTPUT TAPE MPT,40,KA
40    FORMAT(1H1I4////////)
      WRITE OUTPUT TAPE MPT,45,ND(2),NV(2)
45    FORMAT(30X,30X,35X,I4,1H/I3///)
      MB1=11
      MB2=18
55    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=MB1,MB2)
50    FORMAT(4X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-130)55,55,60
60    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=133,140)
      WRITE OUTPUT TAPE MPT,65,ND(141),NV(141)
65    FORMAT(4X,I4,1H/I3)
      RETURN
      END
```

```
      SUBROUTINE F4(FDP,FVP,DD,VV)
      COMMON O
      EQUIVALENCE (O(143),IP(141)),(O(2196),FV(141),FD(282)),(O(2),MPT)
      DIMENSION FDP(201),FVP(201),VV(201),DD(201),IP(141),FD(141),FV(141
     1)
      IF(SENSE SWITCH 4)30,35
30    WRITE OUTPUT TAPE MPT,40,(FDP(I),DD(I),FVP(I),VV(I),I=1,201)
40    FORMAT(8F10.5)
35    DO 10 I=1,141
      II=IP(I)
      IF(FDP(II)-999.0)20,15,15
20    IF(DD(II)-999.0)25,15,15
25    IF(ABSF(DD(II)-FDP(II))-180.0)65,65,60
60    IF(DD(II)-FDP(II))70,75,75
70    DD(II)=DD(II)+360.0
      GO TO 65
75    FDP(II)=FDP(II)+360.0
65    FD(I)=DD(II)-FDP(II)
      FV(I)=VV(II)-FVP(II)
      GO TO 10
15    FD(I)=999.0
      FV(I)=99.0
10    CONTINUE
      IF(SENSE SWITCH 4)45,50
45    WRITE OUTPUT TAPE MPT,55,(FD(I),FV(I),I=1,141)
55    FORMAT(10F10.5)
50    RETURN
      END
```

```
      FUNCTION KPS(K)
      KPS=K+1
      IF(KPS-3)1,1,2
2     KPS=KPS-3
1     RETURN
      END
```

Program "FCST2" uses the kinematic method for computing a 24 hour forecast. The input data may be either unsmoothed or smoothed.

FLOW DIAGRAM



SYMBOL DEFINITIONS

All symbols are the same as those used in the corresponding subroutines or the main program for "FCST" except KL1, KL2, KK, KR2, and KR1 which are used in place of KL, KK, and KR to control the cycling of the data.

```
C FCST2
      COMMON O
      DIMENSION O(3100)
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2716),TIM),(O(3000),
     2FV(141),FD(282)),(O(3003),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,5),DD(201,5),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=24.0
      KL1=1
      KL2=2
      KK=3
      KR2=4
      KR1=5
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL1,KL2,KK,KR2,KR1,K,IK,(DD(I,K),VV(I,K),
     1I=1,201)
 90   FORMAT(7I6/(10F10.0))
 85   IF(IK-5)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL1,KK)
      CALL F3(1)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR1),VV(1,KR1))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR1),VV(1,KR1))
      CALL F3(3)
```

```
      KL1=KPS(KL1)
      KL2=KPS(KL2)
      KK=KPS(KK)
      KR2=KPS(KR2)
      KR1=KPS(KR1)
      K=KR1
      GO TO 65
      END
```

```
      SUBROUTINE F1
      COMMON O
      EQUIVALENCE (O(707),IP4(141),IP3(282),IP2(423),IP1(564),IP(705),IP
     1T(707),MPT(706))
      DIMENSION IP(141),IP1(141),IP2(141),IP3(141),IP4(141)
      READ INPUT TAPE IPT,10,(IP(I),IP1(I),IP2(I),IP3(I),IP4(I),I=1,141)
10    FORMAT(5I5)
      IF(SENSE SWITCH 3)15,20
15    WRITE OUTPUT TAPE MPT,25,(IP(I),IP1(I),IP2(I),IP3(I),IP4(I),I=1,14
     11)
25    FORMAT(I10,4I5,I10,4I5)
20    RETURN
      END
```

```
      SUBROUTINE F2(K1,K2)
      COMMON O
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2718),TIM),(O(3000),
     2FV(141),FD(282))
      DIMENSION IP(141),IP1(141),IP2(141),IP3(141),IP4(141),DD(201,5),
     1VV(201,5),U(201,2),V(201,2),FD(141),FV(141)
      D=2.0*3.0
      RAD=0.01745329
      K=K1
      IK=1
25    DO 10 I=1,201
      IF(VV(I ,K)-99.0)40,35,40
35    U(I,IK)=999.0
      V(I,IK)=999.0
      GO TO 10
40    U(I,IK)=-VV(I ,K)*SINF(DD(I ,K)*RAD)
      V(I,IK)=-VV(I ,K)*COSF(DD(I ,K)*RAD)
10    CONTINUE
      IF(SENSE SWITCH 3)125,130
125   WRITE OUTPUT TAPE MPT,135,K,IK,(U(I,IK),V(I,IK),I=1,201)
135   FORMAT(2I6/(10F10.5))
130   IF(IK-2)20,15,15
20    K=K2
      IK=2
      GO TO 25
15    DO 30 I=1,141
      II=IP(I)
      I1=IP1(I)
      I2=IP2(I)
      I3=IP3(I)
      I4=IP4(I)
      IF(U(II,1)-999.0)45,75,75
45    IF(U(II,2)-999.0)50,75,75
50    IF(U(I1,2)-999.0)55,75,75
55    IF(U(I2,2)-999.0)60,75,75
60    IF(U(I3,2)-999.0)65,75,75
65    IF(U(I4,2)-999.0)70,75,75
75    FD(I)=999.0
      FV(I)=99.0
      GO TO 30
70    DUDX=(U(I3,2)-U(I1,2))/D
      DUDY=(U(I4,2)-U(I2,2))/D
      DVDX=(V(I3,2)-V(I1,2))/D
      DVDY=(V(I4,2)-V(I2,2))/D
      DVDT=(V(II,2)-V(II,1))/TIM
      DUDT=(U(II,2)-U(II,1))/TIM
      DE=DUDX*DVDY-DUDY*DVDX
      CX=(DUDY*DVDT-DVDY*DUDT)/DE
      CY=(DVDX*DUDT-DUDX*DVDT)/DE
      IF(SENSE SWITCH 2)140,145
140   WRITE OUTPUT TAPE MPT,150,I,II,I1,I2,I3,I4,DUDX,DUDY,DVDX,DVDY,DVD
     1T,DUDT,DE,CX,CY
150   FORMAT(6I6/9F10.5)
145   DUDT=(-CX*DUDX-CY*DUDY)*TIM
      DVDT=(-CX*DVDX-CY*DVDY)*TIM
```

```
      UF=U(II,2)+DUDT
      VF=V(II,2)+DVDT
      IF(SENSE SWITCH 2)155,160
155   WRITE OUTPUT TAPE MPT,165,DUDT,DVDT,UF,VF
165   FORMAT(4F10.5'
160   FV(I)=SQRTF(UF*UF+VF*VF)
      IF(VF)80,85,80
85    IF(UF)90,95,100
95    FD(I)=0.0
      GO TO 30
90    FD(I)=90.0
      GO TO 30
100   FD(I)=270.0
      GO TO 30
80    FD(I)=ATANF(UF/VF)/RAD
      IF(UF)110,105,105
110   IF(VF)30,115,115
115   FD(I)=FD(I)+180.0
      GO TO 30
105   IF(VF)120,115,115
120   FD(I)=FD(I)+360.0
30    CONTINUE
      IF(SENSE SWITCH 2)170,175
170   WRITE OUTPUT TAPE MPT,180,(FD(I),FV(I),I=1,141)
180   FORMAT(10F10.2)
175   RETURN
      END
```

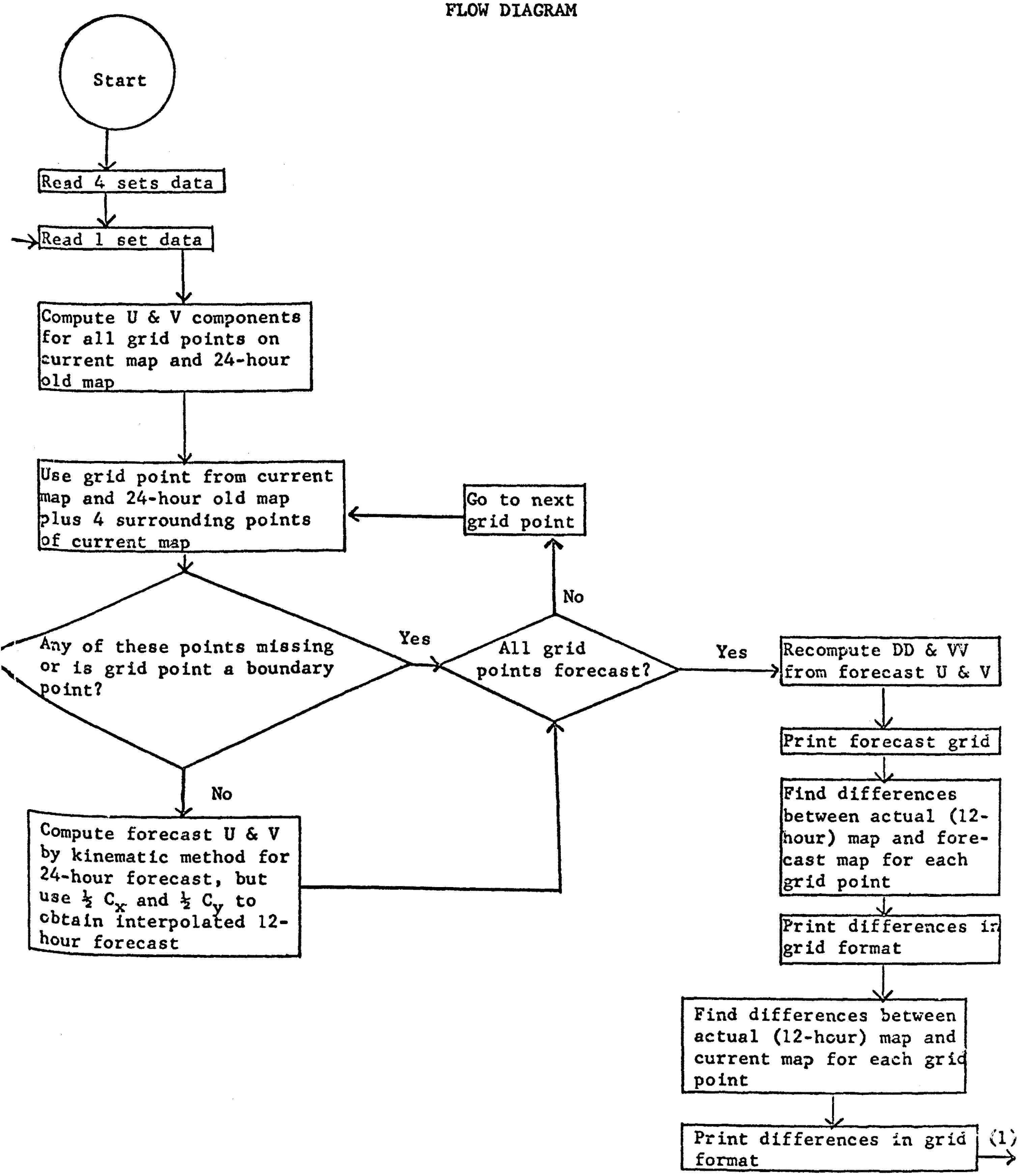
```
      SUBROUTINE F3(I)
      COMMON O
      EQUIVALENCE(O(3000),FV(141),FD(282)),(O(3003),TIME(2),DATE(3),KA(1
     1)),(O(2),MPT)
      DIMENSION FD(141),FV(141),ND(141),NV(141)
      IF(I-2)70,75,80
70    WRITE OUTPUT TAPE MPT,10,KA,DATE,TIME
10    FORMAT(1H1I4,A8,A3,17H 24 HOUR FORECAST///////)
      GO TO 85
75    WRITE OUTPUT TAPE MPT,11,KA,DATE,TIME
11    FORMAT(1H1I4,A8,A3,43H DIFFERENCE BETWEEN ACTUAL MAP AND FORECAST/
     1//////)
      GO TO 85
80    WRITE OUTPUT TAPE MPT,12,KA,DATE,TIME
12    FORMAT(1H1I4,A8,A3,26H DIFFERENCE BY PERSISTENCE///////)
85    DO 90 I=1,141
      ND(I)=FD(I)
90    NV(I)=FV(I)
      WRITE OUTPUT TAPE MPT,15, ND(1),NV(1)
15    FORMAT(30X,I4,1H/I3///)
      MB1=3
      MB2=10
25    WRITE OUTPUT TAPE MPT,20,(ND(I),NV(I),I=MB1,MB2)
20    FORMAT(17X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-122)25,25,30
30    WRITE OUTPUT TAPE MPT,35,(ND(I),NV(I),I=131,132)
35    FORMAT(35X,35X,25X,I4,1H/I3,5X,I4,1H/I3)
      WRITE OUTPUT TAPE MPT,40,KA
40    FORMAT(1H1I4///////)
      WRITE OUTPUT TAPE MPT,45,ND(2),NV(2)
45    FORMAT(30X,30X,35X,I4,1H/I3///)
      MB1=11
      MB2=18
55    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=MB1,MB2)
50    FORMAT(4X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-130)55,55,60
60    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=133,140)
      WRITE OUTPUT TAPE MPT,65,ND(141),NV(141)
65    FORMAT(4X,I4,1H/I3)
      RETURN
      END
```

```
      SUBROUTINE F4(FDP,FVP,DD,VV)
      COMMON O
      EQUIVALENCE (O(143),IP(141)),(O(3000),FV(141),FD(282)),(O(2),MPT)
      DIMENSION FDP(201),FVP(201),VV(201),DD(201),IP(141),FD(141),FV(141
     1)
      IF(SENSE SWITCH 4)30,35
30    WRITE OUTPUT TAPE MPT,40,(FDP(I),DD(I),FVP(I),VV(I),I=1,201)
40    FORMAT(8F10.5)
35    DO 10 I=1,141
      II=IP(I)
      IF(FDP(II)-999.0)20,15,15
20    IF(DD(II)-999.0)25,15,15
25    IF(ABSF(DD(II)-FDP(II))-180.0)65,65,60
60    IF(DD(II)-FDP(II))70,75,75
70    DD(II)=DD(II)+360.0
      GO TO 65
75    FDP(II)=FDP(II)+360.0
65    FD(I)=DD(II)-FDP(II)
      FV(I)=VV(II)-FVP(II)
      GO TO 10
15    FD(I)=999.0
      FV(I)=99.0
10    CONTINUE
      IF(SENSE SWITCH 4)45,50
45    WRITE OUTPUT TAPE MPT,55,(FD(I),FV(I),I=1,141)
55    FORMAT(10F10.5)
50    RETURN
      END
```

```
      FUNCTION KPS(K)
      KPS=K+1
      IF(KPS-5)1,1,2
2     KPS=KPS-5
1     RETURN
      END
```

Program "FCST3" uses the kinematic method to compute a 12 hour forecast from a 24 hour forecast by using ½ C_x and ½ C_y. The input data may be either unsmoothed or smoothed. Subroutines F1, F3, F4, and function KPS are the same as listed for program "FCST2".

FLOW DIAGRAM



SYMBOL DEFINITIONS

All symbols are the same as those used in the corresponding subroutines or the main program for "FCST2".

```
C FCST3
      COMMON O
      DIMENSION O(3100)
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2718),TIM),(O(3000),
     2FV(141),FD(282)),(O(3003),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,5),DD(201,5),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=24.0
      KL1=1
      KL2=2
      KK=3
      KR2=4
      KR1=5
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL1,KL2,KK,KR2,KR1,K,IK,(DD(I,K),VV(I,K),
     1I=1,201)
 90   FORMAT(7I6/(10F10.0))
 85   IF(IK-5)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL1,KK)
      CALL F3(1)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR2),VV(1,KR2))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR2),VV(1,KR2))
      CALL F3(3)
```

```
KL1=KPS(KL1)
KL2=KPS(KL2)
KK=KPS(KK)
KR2=KPS(KR2)
KR1=KPS(KR1)
K=KR1
GO TO 65
END
```

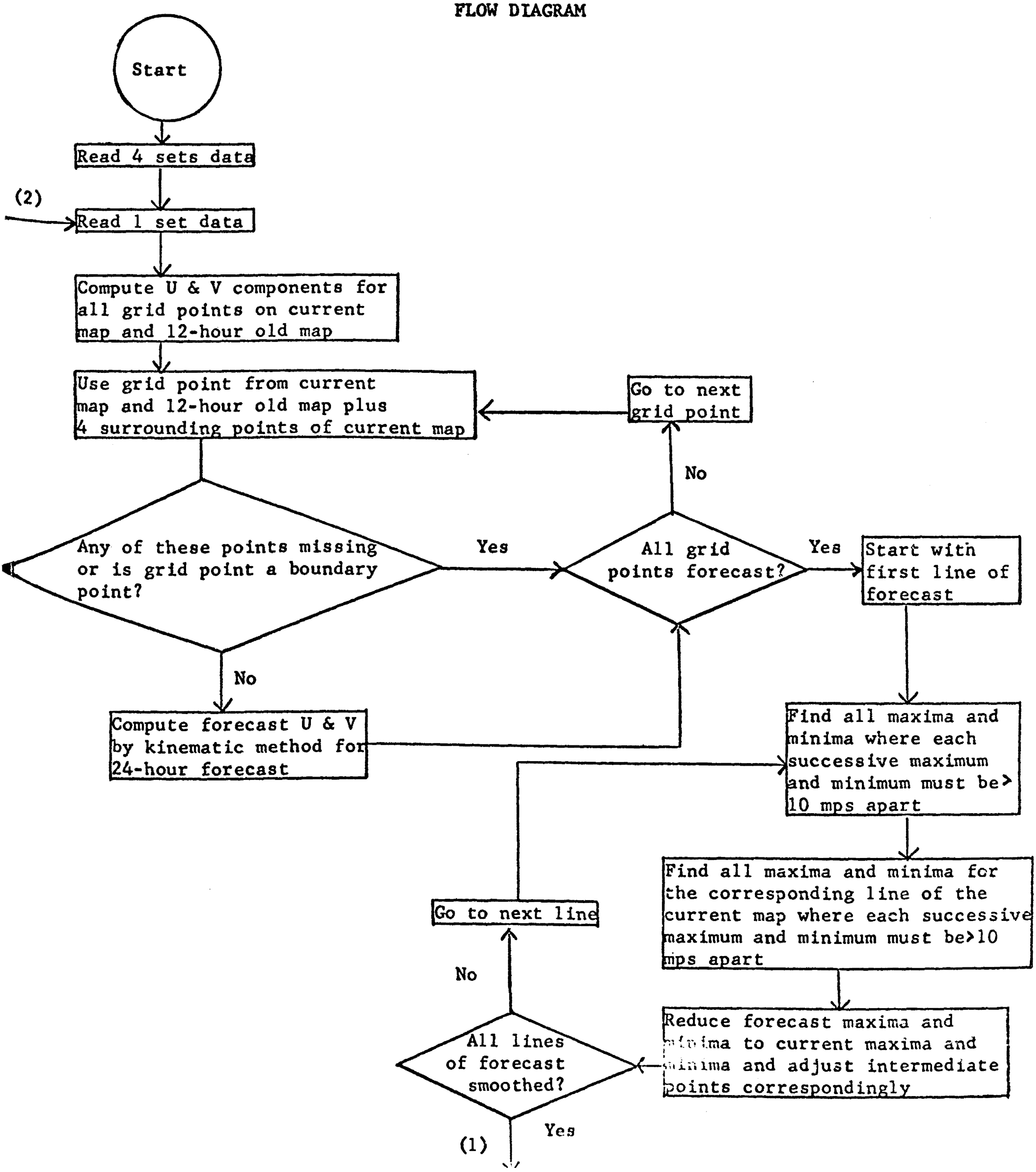
```
      SUBROUTINE F2(K1,K2)
      COMMON O
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2718),TIM),(O(3000),
     2FV(141),FD(282))
      DIMENSION IP(141),IP1(141),IP2(141),IP3(141),IP4(141),DD(201,5),
     1VV(201,5),U(201,2),V(201,2),FD(141),FV(141)
      D=2.0*3.0
      RAD=0.01745329
      K=K1
      IK=1
25    DO 10 I=1,201
      IF(VV(I ,K)-99.0)40,35,40
35    U(I,IK)=999.0
      V(I,IK)=999.0
      GO TO 10
40    U(I,IK)=-VV(I ,K)*SINF(DD(I ,K)*RAD)
      V(I,IK)=-VV(I ,K)*COSF(DD(I ,K)*RAD)
10    CONTINUE
      IF(SENSE SWITCH 3)125,130
125   WRITE OUTPUT TAPE MPT,135,K,IK,(U(I,IK),V(I,IK),I=1,201)
135   FORMAT(2I6/(10F10.5))
130   IF(IK-2)20,15,15
20    K=K2
      IK=2
      GO TO 25
15    DO 30 I=1,141
      II=IP(I)
      I1=IP1(I)
      I2=IP2(I)
      I3=IP3(I)
      I4=IP4(I)
      IF(U(II,1)-999.0)45,75,75
45    IF(U(II,2)-999.0)50,75,75
50    IF(U(I1,2)-999.0)55,75,75
55    IF(U(I2,2)-999.0)60,75,75
60    IF(U(I3,2)-999.0)65,75,75
65    IF(U(I4,2)-999.0)70,75,75
75    FD(I)=999.0
      FV(I)=99.0
      GO TO 30
70    DUDX=(U(I3,2)-U(I1,2))/D
      DUDY=(U(I4,2)-U(I2,2))/D
      DVDX=(V(I3,2)-V(I1,2))/D
      DVDY=(V(I4,2)-V(I2,2))/D
      DVDT=(V(II,2)-V(II,1))/TIM
      DUDT=(U(II,2)-U(II,1))/TIM
      DE=(DUDX*DVDY-DUDY*DVDX)*2.0
      CX=(DUDY*DVDT-DVDY*DUDT)/DE
      CY=(DVDX*DUDT-DUDX*DVDT)/DE
      IF(SENSE SWITCH 2)140,145
140   WRITE OUTPUT TAPE MPT,150,I,II,I1,I2,I3,I4,DUDX,DUDY,DVDX,DVDY,DVD
     1T,DUDT,DE,CX,CY
150   FORMAT(6I6/9F10.5)
145   DUDT=(-CX*DUDX-CY*DUDY)*TIM
      DVDT=(-CX*DVDX-CY*DVDY)*TIM
```

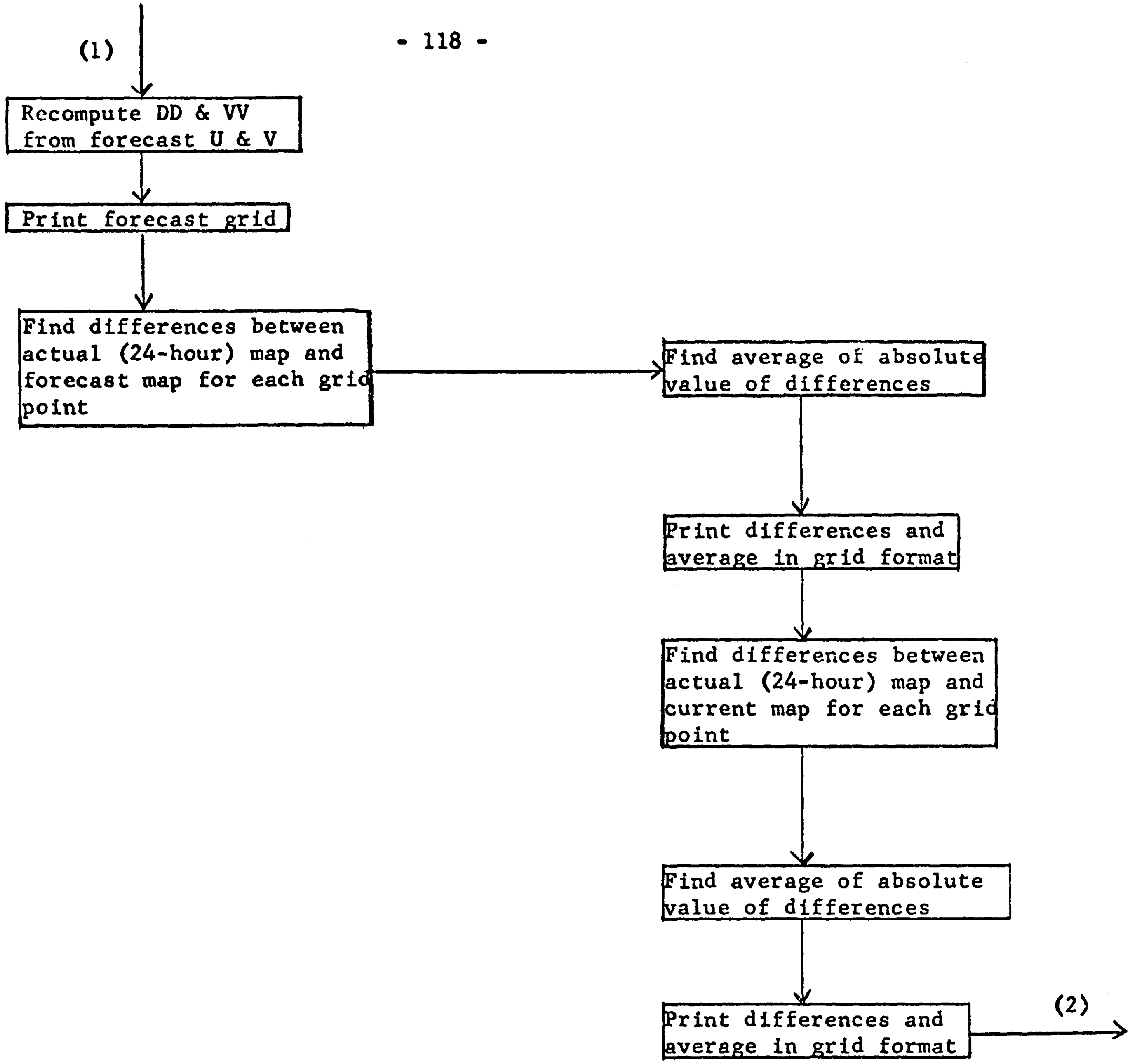
```
      UF=U(II,2)+DUDT
      VF=V(II,2)+DVDT
      IF(SENSE SWITCH 2)155,160
155   WRITE OUTPUT TAPE MPT,165,DUDT,DVDT,UF,VF
165   FORMAT(4F10.5)
160   FV(I)=SQRTF(UF*UF+VF*VF)
      IF(VF)80,85,80
85    IF(UF)90,95,100
95    FD(I)=0.0
      GO TO 30
90    FD(I)=90.0
      GO TO 30
100   FD(I)=270.0
      GO TO 30
80    FD(I)=ATANF(UF/VF)/RAD
      IF(UF)110,105,105
110   IF(VF)30,115,115
115   FD(I)=FD(I)+180.0
      GO TO 30
105   IF(VF)120,115,115
120   FD(I)=FD(I)+360.0
30    CONTINUE
      IF(SENSE SWITCH 2)170,175
170   WRITE OUTPUT TAPE MPT,180,(FD(I),FV(I),I=1,141)
180   FORMAT(10F10.2)
175   RETURN
      END
```

Appendix 6: Programs for 12 and 24 hour forecasts with smoothing.

Program "FCST4" uses the kinematic method for computing a 24 hour forecast. The forecast is smoothed by scanning for maxima and minima. The input data may be either unsmoothed or smoothed. Subroutines F1, F2, F4 and function KPS are the same as listed for program "FCST2", Appendix 5.

FLOW DIAGRAM





SYMBOL DEFINITIONS

All symbols used in the main program, in subroutines F1, F2, and F4, and in function KPS are the same as those defined for "FCST2", Appendix 5. Symbols used in subroutines F3 and F5 are the same as in "FCST2" with the addition of the following symbols.

SUBROUTINE F3

Others:

1. SFD - average of absolute value of differences between actual and forecast directions
2. SFV - average of absolute value of differences between actual and forecast speeds
3. SDV - number of differences computed

SUBROUTINE F5

Others:

1. FMAXU - maximum U component
2. FMAXV - maximum V component
3. IU - subscript locating FMAXU
4. IV - subscript locating FMAXV
5. FMAXUO - first maximum U component on line
6. FMAXVO - first maximum V component on line
7. FMX - maximum values on line
8. IMX - subscripts locating FMX
9. FMI - minimum values on line
10. IMX - subscripts locating FMI
11. FMXO - saves maximum values on line
12. FMIO - saves minimum values on line
13. FDS - saves smoothed U components while V components are smoothed

COMPUTER TIME

24-hour forecasts of LMW winds with scanning procedure consume approximately 6 seconds per map.

```
C FCST4
      COMMON O
      DIMENSION O(3100)
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2718),TIM),(O(3000),
     2FV(141),FD(282)),(O(3003),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,5),DD(201,5),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=24.0
      KL1=1
      KL2=2
      KK=3
      KR2=4
      KR1=5
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL1,KL2,KK,KR2,KR1,K,IK,(DD(I,K),VV(I,K),
     1I=1,201)
 90   FORMAT(7I6/(10F10.0))
 85   IF(IK-5)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL1,KK)
      CALL F5(KK)
      VMS=0.0
      CALL F3(1,VMS)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR1),VV(1,KR1),VMS)
      CALL F3(2,VMS)
```

```
CALL F4(DD(1,KK),VV(1,KK),DD(1,KR1),VV(1,KR1),VMS)
CALL F3(3,VMS)
KL1=KPS(KL1)
KL2=KPS(KL2)
KK=KPS(KK)
KR2=KPS(KR2)
KR1=KPS(KR1)
K=KR1
GO TO 65
END
```

```
      SUBROUTINE F3(II,VMS)
      COMMON O
      EQUIVALENCE(O(3000),FV(141),FD(282)),(O(3003),TIME(2),DATE(3),KA(1
     1)),(O(2),MPT)
      DIMENSION FD(141),FV(141),ND(141),NV(141)
      IF(II-2)70,75,80
70    WRITE OUTPUT TAPE MPT,10,KA,DATE,TIME
10    FORMAT(1H1I4,A8,A3,17H 24 HOUR FORECAST///////)
      GO TO 85
75    WRITE OUTPUT TAPE MPT,11,KA,DATE,TIME
11    FORMAT(1H1I4,A8,A3,43H DIFFERENCE BETWEEN ACTUAL MAP AND FORECAST/
     1///////)
      GO TO 85
80    WRITE OUTPUT TAPE MPT,12,KA,DATE,TIME
12    FORMAT(1H1I4,A8,A3,26H DIFFERENCE BY PERSISTENCE///////)
85    DO 90 I=1,141
      ND(I)=FD(I)
90    NV(I)=FV(I)
      WRITE OUTPUT TAPE MPT,15, ND(1),NV(1)
15    FORMAT(30X,I4,1H/I3///)
      MB1=3
      MB2=10
25    WRITE OUTPUT TAPE MPT,20,(ND(I),NV(I),I=MB1,MB2)
20    FORMAT(17X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-122)25,25,30
30    WRITE OUTPUT TAPE MPT,35,(ND(I),NV(I),I=131,132)
35    FORMAT(35X,35X,25X,I4,1H/I3,5X,I4,1H/I3)
      WRITE OUTPUT TAPE MPT,40,KA
40    FORMAT(1H1I4///////)
      WRITE OUTPUT TAPE MPT,45,ND(2),NV(2)
45    FORMAT(30X,30X,35X,I4,1H/I3///)
      MB1=11
      MB2=18
55    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=MB1,MB2)
50    FORMAT(4X,7(I4,1H/I3,5X),I4,1H/I3///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-130)55,55,60
60    WRITE OUTPUT TAPE MPT,50,(ND(I),NV(I),I=133,140)
      WRITE OUTPUT TAPE MPT,65,ND(141),NV(141)
65    FORMAT(4X,I4,1H/I3)
      IF(II-2)100,105,105
105   SFD=0.0
      SFV=0.0
      SDV=0.0
      DO 110 I=1,141
      IF(FD(I)-999.0)115,110,115
115   SFD=SFD+ABSF(FD(I))
      SFV=SFV+ABSF(FV(I))
      SDV=SDV+1.0
110   CONTINUE
      SFD=SFD/SDV
      SFV=SFV/SDV
      WRITE OUTPUT TAPE MPT,120,SFD,SFV,VMS
```

```
120   FORMAT(///30X,30X,30X,10X,F4.0,1H/F3.0,F10.3)
100   RETURN
      END
```

```
      SUBROUTINE F5(KK)
      COMMON O
      EQUIVALENCE (O(2717),DD(1005),VV(2010)),(O(3000),FV(141),FD(282)),
     1(O(143),IP(141))
      DIMENSION VV(201,5),DD(201,5),FV(141),FD(141),U(141),V(141),IP(141
     1),FMXO(18),FMIO(18),FMX(18),N(18),IMX(18),FMI(18),IMI(18),FDS(141)
     2,KI(18)
     3,IJO(18),IJ(18)
      RAD=0.01745329
      DO 10 I=1,141
      IF(FD(I)-999.0)100,105,105
105   FV(I)=999.0
      GO TO 106
100   D=-FV(I)*SINF(FD(I)*RAD)
      FV(I)=-FV(I)*COSF(FD(I)*RAD)
      FD(I)=D
106   II=IP(I)
      IF(DD(II,KK)-999.0)110,115,115
115   U(I)=999.0
      V(I)=999.0
      GO TO 10
110   U(I)=-VV(II,KK)*SINF(DD(II,KK)*RAD)
      V(I)=-VV(II,KK)*COSF(DD(II,KK)*RAD)
10    CONTINUE
      IF(SENSE SWITCH 5)600,610
600   WRITE OUTPUT TAPE 6,605,(U(I),FD(I),V(I),FV(I),I=1,141)
605   FORMAT(4F10.5)
610   IU=1
2050  IF(FD(IU)-999.0)2040,2045,2045
2045  IU=IU+1
      GO TO 2050
2040  FMAXU=FD(IU)
      FMAXV=FV(IU)
      IV=IU
      J=IU+1
      DO 15 I=J,141
      IF(FD(I)-999.0)16,15,15
16    IF(ABSF(FMAXU-FD(I)))20,25,25
20    FMAXU=FD(I)
      IU=I
25    IF(ABSF(FMAXV-FV(I)))30,15,15
30    FMAXV=FV(I)
      IV=I
15    CONTINUE
      J=1
2065  IF(U(J)-999.0)2060,2055,2055
2055  J=J+1
      GO TO 2065
2060  FMAXUO=U(J)
      FMAXVO=V(J)
      J=J+1
      DO 35 I=J,141
      IF(U(I)-999.0)36,35,35
36    IF(ABSF(FMAXUO-U(I)))40,45,45
40    FMAXUO=U(I)
45    IF(ABSF(FMAXVO-V(I)))50,35,35
```

```
50    FMAXVO=V(I)
35    CONTINUE
      IJK1=0
305   MB1=3
      MB2=18
265   IJK=0
175   DO 1450 I=1,18
1450  N(I)=0
      K=1
      I=MB1
      L=1
75    IF(U(I)-999.0)60,55,55
55    I=I+1
      IF(I-MB2)75,75,150
60    GO TO 61
61    IF(U(I+1)-999.0)62,55,55
62    IF(U(I)-U(I+1))95,65,65
65    IJ(K)=1
140   FMX(K)=U(I)
      IMX(K)=I
85    N(K)=N(K)+1
      I=I+1
      IF(I-MB2)70,82,82
82    L=1
      GO TO 90
70    IF(U(I+1)-999.0)80,81,81
81    L=2
      GO TO 90
80    IF(U(I)-U(I+1))91,85,85
91    L=3
90    FMI(K)=U(I)
      IMI(K)=I
      N(K)=N(K)+1
      K=K+1
      IF(U(I+1)-999.0)2010,2015,2015
2015  I=I+1
      IF(I-MB2)2010,150,150
2010  GO TO (150,75,75),L
95    IJ(K)=0
120   FMI(K)=U(I)
      IMI(K)=I
130   N(K)=N(K)+1
      I=I+1
      IF(I-MP2 125,147,147
147   L=1
      GO TO 135
125   IF(U(I+1)-999.0)145,146,146
146   L=3
      GO TO 135
145   IF(U(I+1)-U(I))136,130,130
136   L=2
135   FMX(K)=U(I)
      IMX(K)=I
      N(K)=N(K)+1
      K=K+1
      IF(U(I+1)-999.0)2000,2005,2005
```

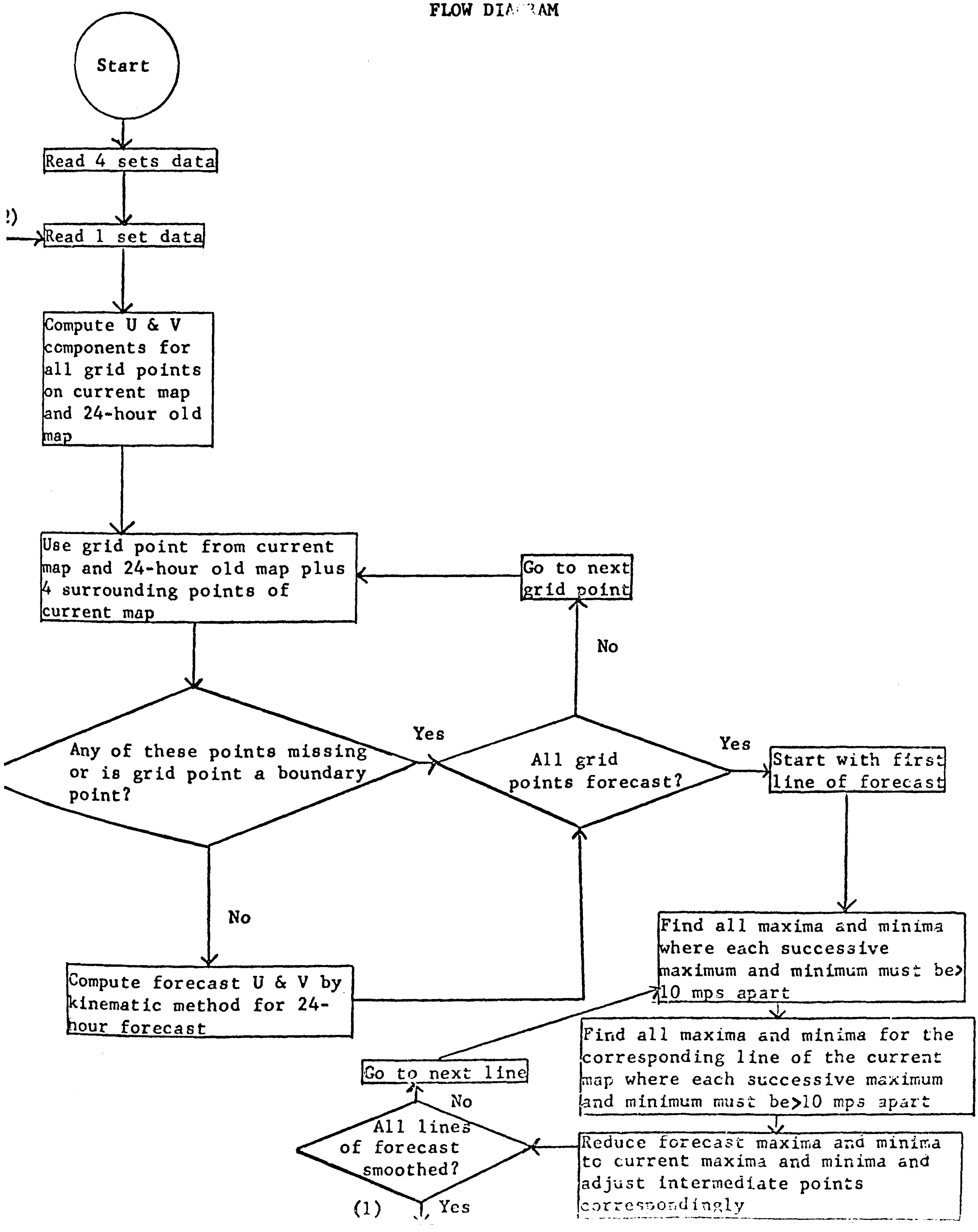
```
2005 I=I+1
     IF(I-MB2)2000,150,150
2000 GO TO (150,75,75),L
150  K=K-1
     I1=0
     IF(FMX(1)-FMI(1)-10.0)3000,3005,3005
3000 IF(IJ(1))3010,3010,3015
3010 IJ(1)=1
     FMX(1)=FMI(1)
     IMX(1)=IMI(1)
     GO TO 3005
3015 IJ(1)=0
     FMI(1)=FMX(1)
     IMI(1)=IMX(1)
3005 K2=0
     DO 3020 I=2,K
     IF(FMX(I)-FMI(I)-10.0)3019,3025,3025
3025 K2=K2+1
     KI(K2)=I
     GO TO 3020
3019 IF(I-K)3020,3018,3020
3018 I1=1
3020 CONTINUE
     K1=K2+I1
     IF(K1)3022,3022,3021
3021 IF(IJ(1))3030,3030,3035
3030 K2=1
     II=KI(K2)
     FMX(1)=FMX(II)
     IMX(1)=IMX(II)
     I=2
3050 IF(I-K1)3040,3040,3060
3040 IJ(I)=1
     FMX(I)=FMX(II)
     IMX(I)=IMX(II)
     K2=K2+1
     IF(K2-K1)3041,3065,3065
3041 II=KI(K2)
     FMI(I)=FMI(II)
     IMI(I)=IMI(II)
     I=I+1
     GO TO 3055
3035 K2=1
     II=KI(K2)
     FMI(1)=FMI(II)
     IMI(1)=IMI(II)
     I=2
3055 IF(I-K1)3045,3045,3065
3045 IJ(I)=0
     FMI(I)=FMI(II)
     IMI(I)=IMI(II)
     K2=K2+1
     IF(K2-K1)3046,3060,3060
3046 II=KI(K2)
     FMX(I)=FMX(II)
     IMX(I)=IMX(II)
```

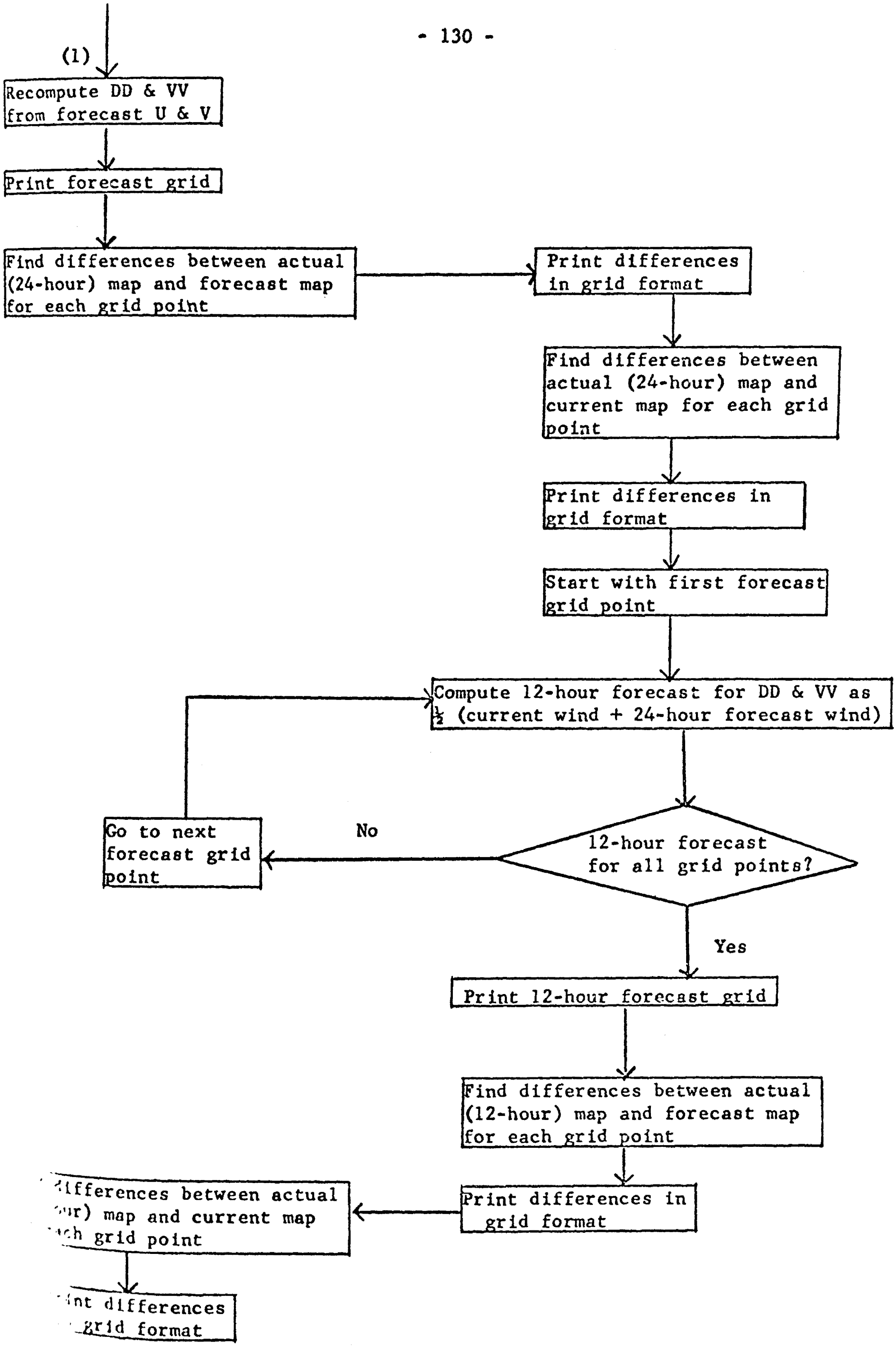
```
      I=I+1
      GO TO 3050
3060  FMX(I)=FMX(K)
      IMX(I)=IMX(K)
      GO TO 3069
3065  FMI(I)=FMI(K)
      IMI(I)=IMI(K)
3069  DO 3070 I=1,K1
3070  N(I)=XABSF(IMX(I)-IMI(I))+1
      K=K1
3022  IF(IJK)155,155,161
155   IJK=1
      DO 165 I=1,K
      FMXO(I)=FMX(I)
      IJO(I)=IJ(I)
165   FMIO(I)=FMI(I)
      KO=K
      DO 170 I=MB1,MB2
170   U(I)=FD(I)
      GOTO 175
161   K1=1
      K2=1
160   IF(IJ(K1))245,245,180
180   IF(IJO(K2))240,240,185
185   GO TO 235
235   FN=N(K1)
      I1=IMX(K1)
      I2=IMI(K1)
      IF(IMX(K1)-IU)205,210,205
210   FMXO(K2)=FMAXUO
205   FD(I1)=FMXO(K2)
      FD(I2)=FMIO(K2)
      I1=I1+1
      I2=I2-1
      IF(I1-I2)2030,2030,2035
2030  DO 190 I=I1,I2
      IF(FD(I)-999.0)191,2035,2035
191   FI=I-I1+2
190   FD(I)=FD(I)+(FMIO(K2)-FMI(K1))*FI/FN-(FMX(K1)-FMXO(K2))*(FN-FI)/FN
2035  K1=K1+1
      K2=K2+1
      IF(K1-K)195,195,260
195   IF(K2-KO)160,160,260
200   FN=N(K1)
      I1=IMI(K1)
      I2=IMX(K1)
      IF(IMX(K1)-IU)220,225,220
225   FMXO(K2)=FMAXUO
220   FD(I1)=FMIO(K2)
      FD(I2)=FMXO(K2)
      I1=I1+1
      I2=I2-1
      IF(I1-I2)2020,2020,2025
2020  DO 215 I=I1,I2
      IF(FD(I)-999.0)216,2025,2025
216   FI=I-I1+2
```

```
215   FD(I)=FD(I)+(FMI0(K2)-FMI(K1))*(FN-FI)/FN-(FMX(K1)-FMX0(K2))*FI/FN
2025  K1=K1+1
      K2=K2+1
      IF(K1-K)230,230,260
230   IF(K2-K0)160,160,260
240   K1=K1+1
      IF(K1-K)160,160,260
245   IF(IJ0(K2))250,250,255
250   GO TO 200
255   K1=K1+1
      IF(K1-K)160,160,260
260   MB1=MB1+16
      MB2=MB2+16
      IF(MB2-130)265,265,270
270   IF(MB2-156)275,280,280
275   MB2=140
      GO TO 265
280   IF(IJK1)290,290,300
290   IJK1=1
      DO 285 I=1,141
      FDS(I)=FD(I)
      FD(I)=FV(I)
285   U(I)=V(I)
      FMAXU0=FMAXV0
      IU=IV
      GO TO 305
300   DO 310 I=1,141
      FV(I)=FD(I)
310   FD(I)=FDS(I)
      IF(SENSE SWITCH 5)615,620
615   WRITE OUTPUT TAPE 6,625,(FD(I),FV(I),I=1,141)
625   FORMAT(2F10.5)
620   DO 315 I=1,141
      IF(FD(I)-999.0)320,325,325
325   FV(I)=99.0
      GO TO 315
320   UF=FD(I)
      VF=FV(I)
      FV(I)=SQRTF(UF*UF+VF*VF)
      IF(VF)480,485,480
485   IF(UF)490,495,500
495   FD(I)=0.0
      GO TO 315
490   FD(I)=90.0
      GO TO 315
500   FD(I)=270.0
      GO TO 315
480   FD(I)=ATANF(UF/VF)/RAD
      IF(UF)510,505,505
510   IF(VF)315,515,515
515   FD(I)=FD(I)+180.0
      GO TO 315
505   IF(VF)520,515,515
520   FD(I)=FD(I)+360.0
315   CONTINUE
      RETURN
      END
```

Program "FCST5" computes a smoothed 24 hour forecast as in "FCST4" and then computes 12 hour forecast as the average value of the current map and the 24 hour forecast map. ıbroutines F1, F2, F3 and F4 and function KPS are the same as listed for program "FCST2", ıpendix 5. Subroutine F5 is the same as listed for program "FCST4".

FLOW DIAGRAM




(1)
Recompute DD & VV from forecast U & V
Print forecast grid
Find differences between actual (24-hour) map and forecast map for each grid point
Print differences in grid format
Find differences between actual (24-hour) map and current map for each grid point
Print differences in grid format
Start with first forecast grid point
Compute 12-hour forecast for DD & VV as ½ (current wind + 24-hour forecast wind)
12-hour forecast for all grid points?
No
Go to next forecast grid point
Yes
Print 12-hour forecast grid
Find differences between actual (12-hour) map and forecast map for each grid point
Print differences in grid format
ifferences between actual
map and current map
grid point
differences
grid format

SYMBOL DEFINITIONS

All symbols used in the main program, in subroutines F1, F2, F3 and F4 and in function KPS are the same as those used in the corresponding subroutines, function or main program of "FCST2", Appendix 5. All symbols used in subroutine F5 are the same as defined for "FCST4". All symbols used in subroutine F6 have been defined in the main program of "FCST2".

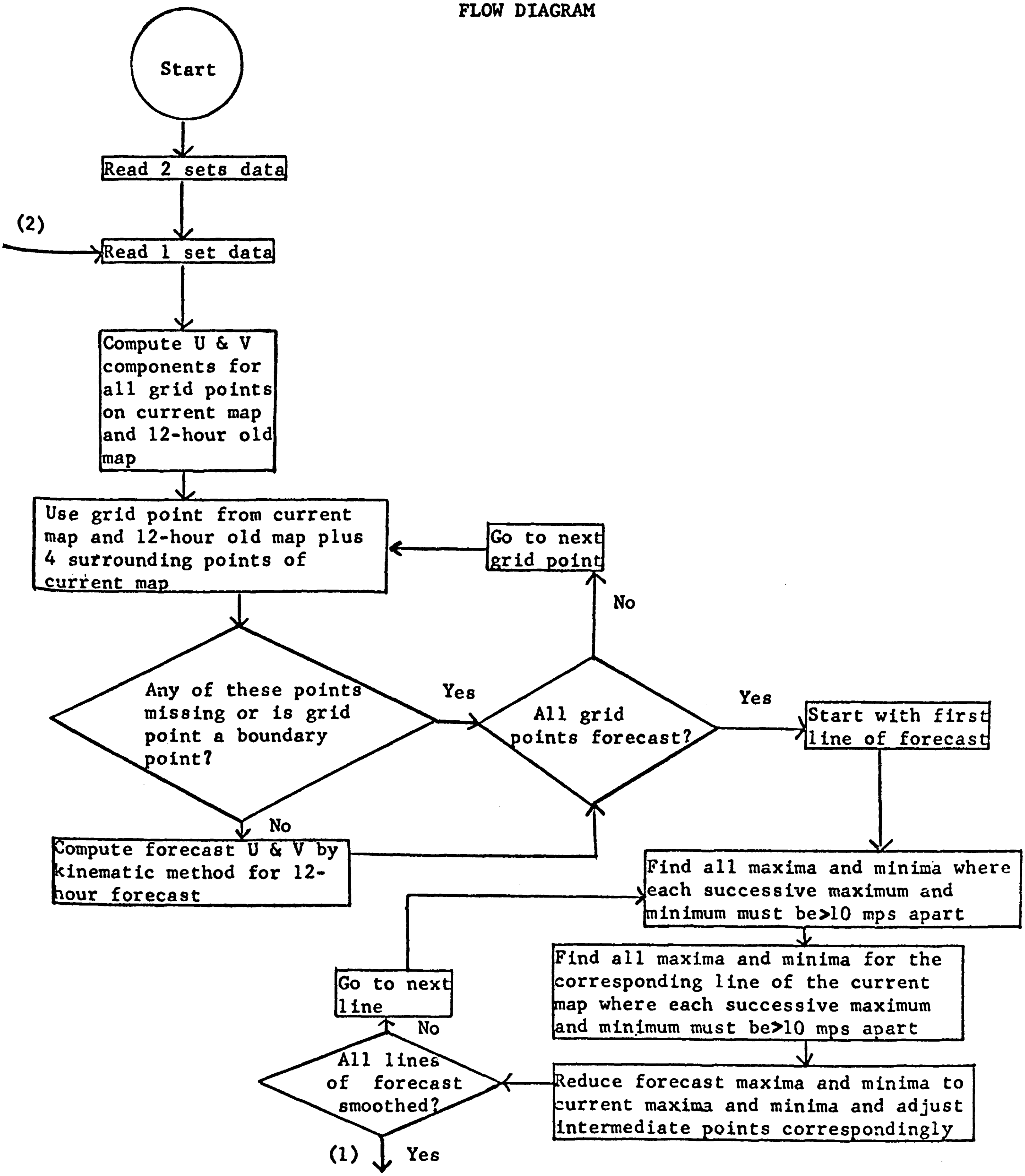
```
C FCST5
      COMMON O
      DIMENSION O(3100)
      EQUIVALENCE(O(2),MPT(1),IPT(2)),(O(2717),DD(1005),VV(2010),IP4(215
     11),IP3(2292),IP2(2433),IP1(2574),IP(2715)),(O(2718),TIM),(O(3000),
     2FV(141),FD(282)),(O(3003),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,5),DD(201,5),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=24.0
      KL1=1
      KL2=2
      KK=3
      KR2=4
      KR1=5
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL1,KL2,KK,KR2,KR1,K,IK,(DD(I,K),VV(I,K),
     1I=1,201)
 90   FORMAT(7I6/(10F10.0))
 85   IF(IK-5)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL1,KK)
      CALL F5(KK)
      CALL F3(1)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR1),VV(1,KR1))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR1),VV(1,KR1))
```

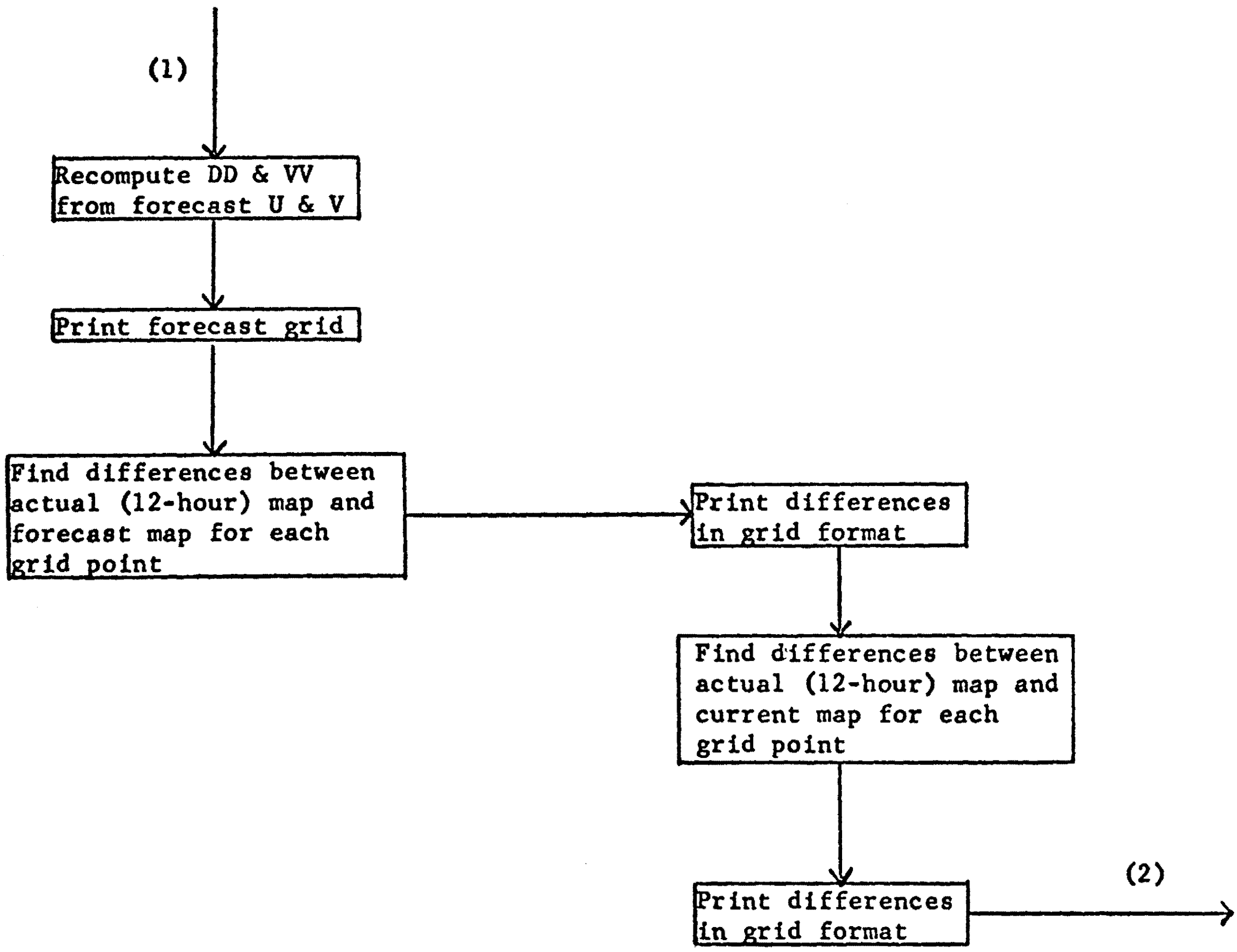
```
      CALL F3(3)
      CALL F6(FDP,FVP,DD(1,KK),VV(1,KK))
      CALL F3(1)
      DO 100 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
100   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR2),VV(1,KR2))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR2),VV(1,KR2))
      CALL F3(3)
      KL1=KPS(KL1)
      KL2=KPS(KL2)
      KK=KPS(KK)
      KR2=KPS(KR2)
      KR1=KPS(KR1)
      K=KR1
      GO TO 65
      END
```

```
      SUBROUTINE F6(FDP,FVP,DD,VV)
      COMMON O
      EQUIVALENCE (O(143),IP(141)),(O(3000),FV(141),FD(282))
      DIMENSION FV(141),FD(141),FDP(201),FVP(201),DD(201),VV(201),IP(141
     )
      DO 10 I=1,141
      II=IP(I)
      IF(FDP(II)-999.0)20,15,15
20    IF(DD(II)-999.0)25,15,15
25    IF(ABSF(DD(II)-FDP(II))-180.0)65,65,60
60    IF(DD(II)-FDP(II))70,75,75
70    DD(II)=DD(II)+360.0
      GO TO  65
75    FDP(II)=FDP(II)+360.0
65    FD(I)=(DD(II)+FDP(II))/2.0
      FV(I)=(VV(II)+FVP(II))/2.0
      IF(FD(I)-360.0)10,80,80
80    FD(I)=FD(I)-360.0
      GO TO 10
15    FD(I)=999.0
      FV(I)=99.0
10    CONTINUE
      RETURN
      END
```

Program "FCST6" uses the kinematic method for computing a 12 hour forecast. The forecast is smoothed by scanning for maxima and minima. The input data may be either unsmoothed or smoothed. Subroutines F1, F2, F3 and F4 and function KPS are the same as listed for program "FCST", Appendix 5.

FLOW DIAGRAM





SYMBOL DEFINITIONS

All symbols used in the main program, in subroutines F1, F2, F3 and F4 and function KPS are the same as those used in the corresponding subroutines, function or main program of "FCST", Appendix 5. All symbols used in subroutine F5 are the same as defined for "FCST4".

```
C FCST6
      COMMON O
      DIMENSION O(3000)
      EQUIVALENCE (O(2),MPT(1),IPT(2)),(O(1913),DD(603),VV(1206),IP4(134
     17),IP3(1488),IP2(1629),IP1(1770),IP(1911)),(O(1914),TIM),(O(2196),
     2FV(141),FD(282)),(O(2200),KA(1),TIME(2),DATE(3))
      DIMENSION VV(201,3),DD(201,3),IP(141),IP1(141),IP2(141),IP3(141),
     1IP4(141),FD(141),FV(141),FDP(201),FVP(201)
      IPT=5
      MPT=6
      DO 70 I=1,201
      FDP(I)=999.0
 70   FVP(I)=99.0
      CALL F1
      READ INPUT TAPE 5,10,D,T
 10   FORMAT(4X,A6,1X,A2)
 40   READ INPUT TAPE IPT,10,D1,T1
      IF(D-D1)25,15,25
 15   IF(T-T1)25,20,25
 25   DO 30 I=1,21
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I4)
 30   CONTINUE
      GO TO 40
 20   BACKSPACE IPT
      TIM=12.0
      KL=1
      KK=2
      KR=3
      K=1
      IK=1
 65   READ INPUT TAPE IPT,45,KA,DATE,TIME
 45   FORMAT(I4,A6,1X,A2)
      READ INPUT TAPE IPT,50,(DD(I,K),VV(I,K),I=1,201)
 50   FORMAT(F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0
     1,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0,F4.0,F3.0)
      IF(SENSE SWITCH 3)80,85
 80   WRITE OUTPUT TAPE MPT,90,KL,KK,KR,K,IK,(DD(I,K),VV(I,K),I=1,201)
 90   FORMAT(5I6/(10F10.0))
 85   IF(IK-3)60,55,55
 60   IK=IK+1
      K=K+1
      GO TO 65
 55   CALL F2(KL,KK)
      CALL F5(KK)
      CALL F3(1)
      DO 75 I=1,141
      II=IP(I)
      FDP(II)=FD(I)
 75   FVP(II)=FV(I)
      CALL F4(FDP,FVP,DD(1,KR),VV(1,KR))
      CALL F3(2)
      CALL F4(DD(1,KK),VV(1,KK),DD(1,KR),VV(1,KR))
      CALL F3(3)
      KL=KPS(KL)
      KK=KPS(KK)
```

```
KR=KPS(KR)
K=KR
GO TO 65
END
```

```
      SUBROUTINE F5(KK)
      COMMON O
      EQUIVALENCE (O(1913),DD(603),VV(1206)),(O(2196),FV(141),FD(282)),(
     1O(143),IP(141))
      DIMENSION VV(201,3),DD(201,3),FV(141),FD(141),U(141),V(141),IP(141
     1),FMXO(18),FMIO(18),FMX(18),N(18),IMX(18),FMI(18),IMI(18),FDS(141)
     2,KI(18)
     3,IJO(18),IJ(18)
      RAD=0.01745329
      DO 10 I=1,141
      IF(FD(I)-999.0)100,105,105
105   FV(I)=999.0
      GO TO 106
100   D=-FV(I)*SINF(FD(I)*RAD)
      FV(I)=-FV(I)*COSF(FD(I)*RAD)
      FD(I)=D
106   II=IP(I)
      IF(DD(II,KK)-999.0)110,115,115
115   U(I)=999.0
      V(I)=999.0
      GO TO 10
110   U(I)=-VV(II,KK)*SINF(DD(II,KK)*RAD)
      V(I)=-VV(II,KK)*COSF(DD(II,KK)*RAD)
10    CONTINUE
      IF(SENSE SWITCH 5)600,610
600   WRITE OUTPUT TAPE 6,605,(U(I),FD(I),V(I),FV(I),I=1,141)
605   FORMAT(4F10.5)
610   IU=1
2050  IF(FD(IU)-999.0)2040,2045,2045
2045  IU=IU+1
      GO TO 2050
2040  FMAXU=FD(IU)
      FMAXV=FV(IU)
      IV=IU
      J=IU+1
      DO 15 I=J,141
      IF(FD(I)-999.0)16,15,15
16    IF(ABSF(FMAXU-FD(I)))20,25,25
20    FMAXU=FD(I)
      IU=I
25    IF(ABSF(FMAXV-FV(I)))30,15,15
30    FMAXV=FV(I)
      IV=I
15    CONTINUE
      J=1
2065  IF(U(J)-999.0)2060,2055,2055
2055  J=J+1
      GO TO 2065
2060  FMAXUO=U(J)
      FMAXVO=V(J)
      J=J+1
      DO 35 I=J,141
      IF(U(I)-999.0)36,35,35
36    IF(ABSF(FMAXUO-U(I)))40,45,45
40    FMAXUO=U(I)
45    IF(ABSF(FMAXVO-V(I)))50,35,35
```

```
50    FMAXVO=V(I)
35    CONTINUE
      IJK1=0
305   MB1=3
      MB2=18
265   IJK=0
175   DO 1450 I=1,18
1450  N(I)=0
      K=1
      I=MB1
      L=1
75    IF(U(I)-999.0)60,55,55
55    I=I+1
      IF(I-MB2)75,75,150
60    GO TO 61
61    IF(U(I+1)-999.0)62,55,55
62    IF(U(I)-U(I+1))95,65,65
65    IJ(K)=1
140   FMX(K)=U(I)
      IMX(K)=I
85    N(K)=N(K)+1
      I=I+1
      IF(I-MB2)70,82,82
82    L=1
      GO TO 90
70    IF(U(I+1)-999.0)80,81,81
81    L=2
      GO TO 90
80    IF(U(I)-U(I+1))91,85,85
91    L=3
90    FMI(K)=U(I)
      IMI(K)=I
      N(K)=N(K)+1
      K=K+1
      IF(U(I+1)-999.0)2010,2015,2015
2015  I=I+1
      IF(I-MB2)2010,150,150
2010  GO TO (150,75,75),L
95    IJ(K)=0
120   FMI(K)=U(I)
      IMI(K)=I
130   N(K)=N(K)+1
      I=I+1
      IF(I-MB2)125,147,147
147   L=1
      GO TO 135
125   IF(U(I+1)-999.0)145,146,146
146   L=3
      GO TO 135
145   IF(U(I+1)-U(I))136,130,130
136   L=2
135   FMX(K)=U(I)
      IMX(K)=I
      N(K)=N(K)+1
      K=K+1
      IF(U(I+1)-999.0)2000,2005,2005
```

```
2005 I=I+1
     IF(I-MB2)2000,150,150
2000 GO TO (150,75,75),L
150  K=K-1
     I1=0
     IF(FMX(1)-FMI(1)-10.0)3000,3005,3005
3000 IF(IJ(1))3010,3010,3015
3010 IJ(1)=1
     FMX(1)=FMI(1)
     IMX(1)=IMI(1)
     GO TO 3005
3015 IJ(1)=0
     FMI(1)=FMX(1)
     IMI(1)=IMX(1)
3005 K2=0
     DO 3020 I=2,K
     IF(FMX(I)-FMI(I)-10.0)3019,3025,3025
3025 K2=K2+1
     KI(K2)=I
     GO TO 3020
3019 IF(I-K)3020,3018,3020
3018 I1=1
3020 CONTINUE
     K1=K2+I1
     IF(K1)3022,3022,3021
3021 IF(IJ(1))3030,3030,3035
3030 K2=1
     II=KI(K2)
     FMX(1)=FMX(II)
     IMX(1)=IMX(II)
     I=2
3050 IF(I-K1)3040,3040,3060
3040 IJ(I)=1
     FMX(I)=FMX(II)
     IMX(I)=IMX(II)
     K2=K2+1
     IF(K2-K1)3041,3065,3065
3041 II=KI(K2)
     FMI(I)=FMI(II)
     IMI(I)=IMI(II)
     I=I+1
     GO TO 3055
3035 K2=1
     II=KI(K2)
     FMI(1)=FMI(II)
     IMI(1)=IMI(II)
     I=2
3055 IF(I-K1)3045,3045,3065
3045 IJ(I)=0
     FMI(I)=FMI(II)
     IMI(I)=IMI(II)
     K2=K2+1
     IF(K2-K1)3046,3060,3060
3046 II=KI(K2)
     FMX(I)=FMX(II)
     IMX(I)=IMX(II)
```

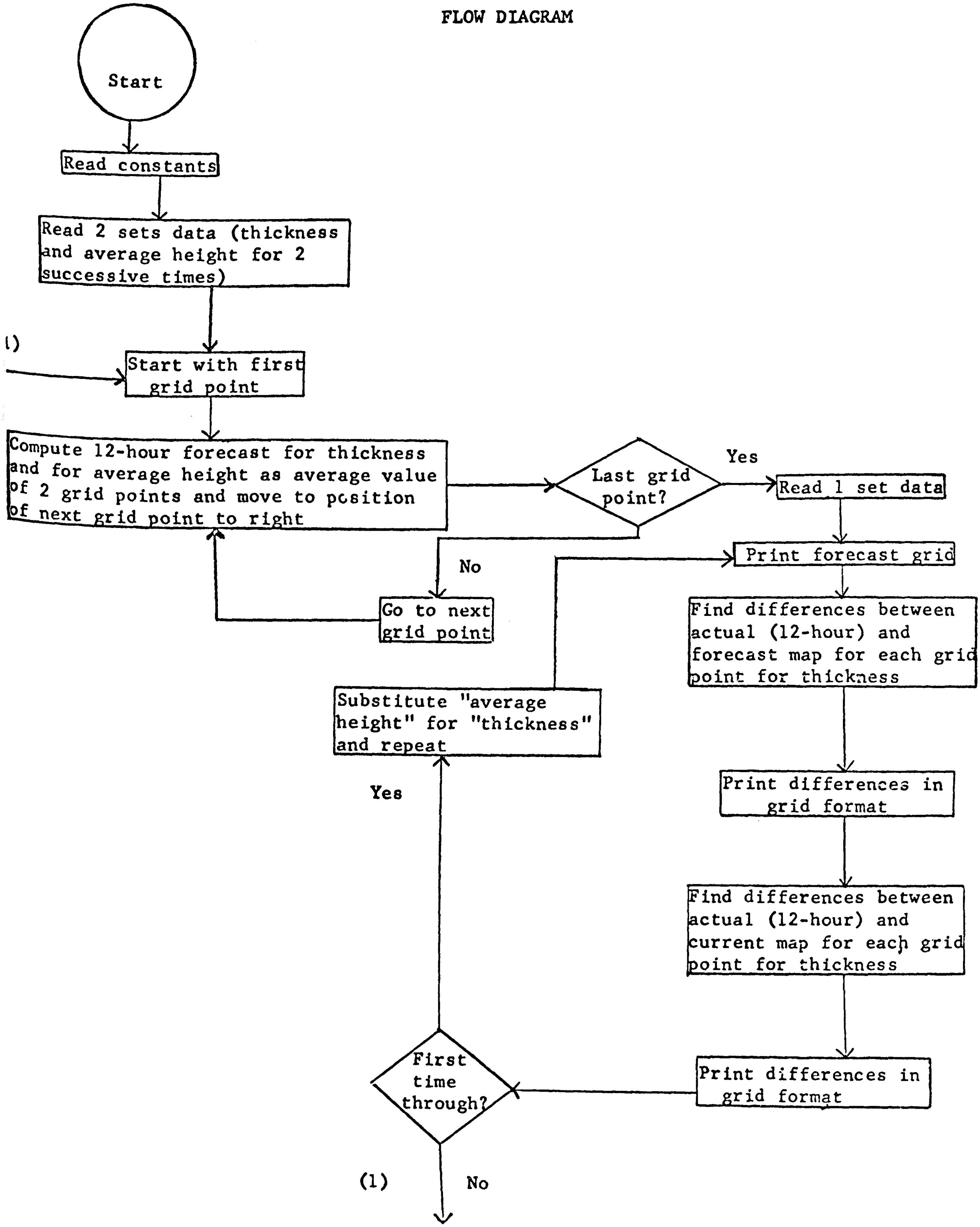
```
      I=I+1
      GO TO 3050
3060  FMX(I)=FMX(K)
      IMX(I)=IMX(K)
      GO TO 3069
3065  FMI(I)=FMI(K)
      IMI(I)=IMI(K)
3069  DO 3070 I=1,K1
3070  N(I)=XABSF(IMX(I)-IMI(I))+1
      K=K1
3022  IF(IJK)155,155,161
155   IJK=1
      DO 165 I=1,K
      FMXO(I)=FMX(I)
      IJO(I)=IJ(I)
165   FMIO(I)=FMI(I)
      KO=K
      DO 170 I=MB1,MB2
170   U(I)=FD(I)
      GOTO 175
161   K1=1
      K2=1
160   IF(IJ(K1))245,245,180
180   IF(IJO(K2))240,240,185
185   GO TO 235
235   FN=N(K1)
      I1=IMX(K1)
      I2=IMI(K1)
      IF(IMX(K1)-IU)205,210,205
210   FMXO(K2)=FMAXUO
205   FD(I1)=FMXO(K2)
      FD(I2)=FMIO(K2)
      I1=I1+1
      I2=I2-1
      IF(I1-I2)2030,2030,2035
2030  DO 190 I=I1,I2
      IF(FD(I)-999.0)191,2035,2035
191   FI=I-I1+2
190   FD(I)=FD(I)+(FMIO(K2)-FMI(K1))*FI/FN-(FMX(K1)-FMXO(K2))*(FN-FI)/FN
2035  K1=K1+1
      K2=K2+1
      IF(K1-K)195,195,260
195   IF(K2-KO)160,160,260
200   FN=N(K1)
      I1=IMI(K1)
      I2=IMX(K1)
      IF(IMX(K1)-IU)220,225,220
225   FMXO(K2)=FMAXUO
220   FD(I1)=FMIO(K2)
      FD(I2)=FMXO(K2)
      I1=I1+1
      I2=I2-1
      IF(I1-I2)2020,2020,2025
2020  DO 215 I=I1,I2
      IF(FD(I)-999.0)216,2025,2025
216   FI=I-I1+2
```

```
215   FD(I)=FD(I)+(FMIO(K2)-FMI(K1))*(FN-FI)/FN-(FMX(K1)-FMXO(K2))*FI/FN
2025  K1=K1+1
      K2=K2+1
      IF(K1-K)230,230,260
230   IF(K2-KO)160,160,260
240   K1=K1+1
      IF(K1-K)160,160,260
245   IF(IJO(K2))250,250,255
250   GO TO 200
255   K1=K1+1
      IF(K1-K)160,160,260
260   MB1=MB1+16
      MB2=MB2+16
      IF(MB2-130)265,265,270
270   IF(MB2-156)275,280,280
275   MB2=140
      GO TO 265
280   IF(IJK1)290,290,300
290   IJK1=1
      DO 285 I=1,141
      FDS(I)=FD(I)
      FD(I)=FV(I)
285   U(I)=V(I)
      FMAXUO=FMAXVO
      IU=IV
      GO TO 305
300   DO 310 I=1,141
      FV(I)=FD(I)
310   FD(I)=FDS(I)
      IF(SENSE SWITCH 5)615,620
615   WRITE OUTPUT TAPE 6,625,(FD(I),FV(I),I=1,141)
625   FORMAT(2F10.5)
620   DO 315 I=1,141
      IF(FD(I)-999.0)320,325,325
325   FV(I)=99.0
      GO TO 315
320   UF=FD(I)
      VF=FV(I)
      FV(I)=SQRTF(UF*UF+VF*VF)
      IF(VF)480,485,480
485   IF(UF)490,495,500
495   FD(I)=0.0
      GO TO 315
490   FD(I)=90.0
      GO TO 315
500   FD(I)=270.0
      GO TO 315
480   FD(I)=ATANF(UF/VF)/RAD
      IF(UF)510,505,505
510   IF(VF)315,515,515
515   FD(I)=FD(I)+180.0
      GO TO 315
505   IF(VF)520,515,515
520   FD(I)=FD(I)+360.0
315   CONTINUF
      RETURN
      END
```

Appendix 7: Program for 12 hour forecast of thickness and average height.

Program "FCSTH" computes a 12 hour forecast of thickness and average height by moving the value at each grid point one and one-half grid distances to the right.

FLOW DIAGRAM



SYMBOL DEFINITIONS

All variables which are stored in common are defined in the main program or in the first subroutine in which they appear.

Main Program

Input:

1. D1 - first date for computation
2. T1 - first time for computation
3. D - current date
4. T - current time
5. JUNK - used to skip cards which have no needed data on them
6. KA - map number
7. DH - thicknesses of layer of maximum wind
8. HB - average heights of layer of maximum wind

Others:

1. IPT - input tape number
2. MPT - output tape number
3. K1, K2 - subscripts used to control cycling of data
4. FDH - forecast thicknesses
5. IP - subscripts connecting input grid (201 points) to forecast grid (173 points)
6. EH - forecast grid expanded to size of input grid
7. FHB - forecast average heights

SUBROUTINE FH1

Input:

1. IP1 - subscripts of left point used in average for forecast
2. IP2 - subscripts of right point used in average for forecast

SUBROUTINE FH2

No new symbols are used

SUBROUTINE FH3

Output:

1. NH - forecast ready for printing
2. SFH - average of differences between actual and forecast values

Others:

1. SH - number of forecast values
2. FJ - value used for missing data

SUBROUTINE FH4

Others:

1. H - input grid
2. F - expanded forecast grid
3. FH - difference between actual and forecast values at each grid point

COMPUTER TIME

12-hour forecasts of LMW heights and thicknesses consume approximately 12 seconds per map for both parameters.

```
C FCSTH
      COMMON O
      DIMENSION O(2000)
      EQUIVALENCE (O(804),HB(402),DH(804)),(O(1325),MPT(1),IPT(2)),(O(16
     1 71),FHB(173),FDH(346)),(O(1674),T(1),D(2),KA(3)),(O(977),IP(173))
      DIMENSION DH(201,2),HB(201,2),FHB(173),FDH(173),EH(201),IP(173)
      IPT=5
      MPT=6
      CALL FH1
      READ INPUT TAPE 5,10,D1,T1
 10   FORMAT(4X,A6,I3)
 30   READ INPUT TAPE IPT,10,D,T
      IF(D-D1)40,20,40
 20   IF(T-T1)40,15,40
 40   DO25 I=1,35
      READ INPUT TAPE IPT,35,JUNK
 35   FORMAT(I2)
 25   CONTINUE
      GO TO 30
 15   BACKSPACE IPT
      READ INPUT TAPE IPT,45,KA,D,T
 45   FORMAT(I4,A6,I3)
      K1=1
      K2=2
      READ INPUT TAPE IPT,50,(DH(I,K1),I=1,201)
 50   FORMAT (12F6.0)
      READ INPUT TAPE IPT,35,JUNK
      READ INPUT TAPE IPT,50,(HB(I,K1),I=1,201)
 1    CALL FH2(K1)
      READ INPUT TAPE IPT,45,KA,D,T
      READ INPUT TAPE IPT,50,(DH(I,K2),I=1,201)
      READ INPUT TAPE IPT,35,JUNK
      READ INPUT TAPE IPT,50,(HB(I,K2),I=1,201)
      CALL FH3(1,FDH,999)
      DO 55 I=1,173
      II=IP(I)
 55   EH(II)=FDH(I)
      CALL FH4(DH(1,K2),EH,FDH,999)
      CALL FH3(2,FDH,999)
      CALL FH4(DH(1,K2),DH(1,K1),FDH,999)
      CALL FH3(3,FDH,999)
      CALL FH3(1,FHB,99)
      DO 60 I=1,173
      II=IP(I)
 60   EH(II)=FHB(I)
      CALL FH4(HB(1,K2),EH,FHB,99)
      CALL FH3(2,FHB,99)
      CALL FH4(HB(1,K2),HB(1,K1),FHB,99
      CALL FH3(3,FHB,99)
      K=K1
      K1=K2
      K2=K
      GO TO 1
      END
```

```
      SUBROUTINE FH1
      COMMON O
      EQUIVALENCE(O(1323),IP2(173),IP1(346),IP(519)),(O(1324),IPT(1))
      DIMENSION IP(173),IP1(173),IP2(173)
      READ INPUT TAPE IPT,10,(IP1(I),IP2(I),IP(I),I=1,173)
10    FORMAT(5X,3I5)
      RETURN
      END
```

```
      SUBROUTINE FH2(K)
      COMMON O
      EQUIVALENCE(O(804),HB(402),DH(804)),(O(1323),IP2(173),IP1(346)),(O
     1 (1671),FHB(173),FDH(346))
      DIMENSION DH(201,2),HB(201,2),FHB(173),FDH(173),IP1(173),IP2(173)
      DO 10 I=1,173
      I1=IP1(I)
      I2=IP2(I)
      IF(HB(I1,K)-99.0)15,20,15
15    IF(HB(I2,K)-99.0)25,20,25
20    FHB(I)=99.0
      FDH(I)=999.0
      GO TO 10
25    FHB(I)=(HB(I1,K)+HB(I2,K))/2.0
      FDH(I)=(DH(I1,K)+DH(I2,K))/2.0
10    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FH3(K,FH, J)
      COMMON O
      EQUIVALENCE(O(1325),MPT(1)),(O(1674),T(1),D(2),KA(3))
      DIMENSION FH(173),NH(173)
      FJ=J
      IF(K-2) 10,15,20
10    WRITE OUTPUT TAPE MPT,25,KA,D,T
25    FORMAT(1H1I4,A9,I5,17H 12 HOUR FORECAST)
      GO TO 40
15    WRITE OUTPUT TAPE MPT,30,KA,D,T
30    FORMAT(1H1,I4,A9,I5,43H DIFFERENCE BETWEEN ACTUAL MAP AND FORECAST
     1)
      GO TO 40
20    WRITE OUTPUT TAPE MPT,35,KA,D,T
35    FORMAT(1H1,I4,A9,I5,26H DIFFERENCE BY PERSISTENCE)
40    DO 100 I=1,173
100   NH(I)=FH(I)
      WRITE OUTPUT TAPE MPT,45,NH(1)
45    FORMAT(////45X,I6///)
      MB1=3
      MB2=9
55    WRITE OUTPUT TAPE MPT,50,(NH(I),I=MB1,MB2)
50    FORMAT(30X,6(2X,I6,5X),2X,I6///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-153)55,55,60
60    WRITE OUTPUT TAPE MPT,65,NH(163)
65    FORMAT(30X,30X,50X,I6)
      WRITE OUTPUT TAPE MPT,70,KA
70    FORMAT(1H1I4)
      WRITE OUTPUT TAPE MPT,75,NH(2)
75    FORMAT(///30X,30X,50X,I6///)
      MB1=10
      MB2=18
85    WRITE OUTPUT TAPE MPT,80,(NH(I),I=MB1,MB2)
80    FORMAT(4X,8(2X,I6,5X),2X,I6///)
      MB1=MB1+16
      MB2=MB2+16
      IF(MB2-162)85,85,90
90    WRITE OUTPUT TAPE MPT,80,(NH(I),I=164,172)
      WRITE OUTPUT TAPE MPT,95,NH(173)
95    FORMAT(19X,I6)
      IF(K-2)105,110,110
110   SFH=0.0
      SH=0.0
      DO 115 I=1,173
      IF(FH(I)-FJ)120,115,120
120   SFH=SFH+ABSF(FH(I))
      SH=SH+1.0
115   CONTINUE
      SFH=SFH/SH
      WRITE OUTPUT TAPE MPT,125,SFH
125   FORMAT(///30X,30X,30X,10X,F6.0)
105   RETURN
      END
```

```
      SUBROUTINE FH4(H,F,FH,J)
      COMMON O
      EQUIVALENCE (O(977),IP(173))
      DIMENSION IP(173),H(201),F(201),FH(173)
      FJ=J
      DO 10I=1,173
      II=IP(I)
      IF(H(II)-FJ)15,20,15
15    IF(F(II)-FJ)25,20,25
20    FH(I)=FJ
      GO TO 10
25    FH(I)=H(II   )-F(II)
10    CONTINUE
      RETURN
      END
```