FORECASTING THE SPEED OF MOVEMENT OF SELECTED CYCLONES ALONG UPPER-AIR STEERING CHANNELS

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(Original manuscript received 24 November 1952; revised manuscript received 26 January 1953)

ABSTRACT

Following the selection of upper-air steering channels on the basis of the height of the "closed" circulation, an objective technique is developed for forecasting the 24- and 30-hour displacements of surface "lows." Data used in forecasting the displacement are dependent on the selected steering channel and involve temperature gradients within these channels. Results on the original and test data-samples are compared with those of other similar investigations.

1. Introduction

The present investigation of the movement of low-pressure systems was begun as an outgrowth of a study conducted by the writer to develop an objective system for forecasting winter precipitation two days in advance for Tennessee, patterned after the work of Schmidt [1]. In the course of that study, it was found that certain rules were needed which implied a forecast of the speed of movement of pressure systems as an aid in timing the arrival or ending of the rainfall. This, in turn, led to the formation of principles which it was thought would be found valid when applied to the more general problem of forecasting the speed of movement of cyclones.

The rules herein developed are similar in many ways to those formulated by Shafer [2]. Like Shafer's results, these rules offer some support to the suggestions made by Austin and Shapiro [3], who concluded that "the motion part of a pressure change is accompanied by low-level warming in the case of pressure falls and cooling with pressure rises," and further that "these low-level temperature changes are intimately connected with horizontal advection."

2. Evaluation of the temperature-advection term

To test such an idea in terms of its usefulness in the forecasting of pressure systems, it is necessary to formulate models and rules into more or less quantitative statements. Herein are presented rules for a quantitative evaluation of a term approximating temperature advection, for two types of low-pressure systems occurring in the central and eastern United States. The rules are so stated that they result directly in a forecast of the direction and speed of movement of the defined low-pressure areas over 24- and 30-hr intervals. These rules will be found to provide a technique which has some similarity with the method proposed by Shafer; but these rules are believed to offer some advantages in terms of simplicity in evaluation and overall usefulness. It is not suggested here that the method proposed gives an adequate indication of temperature advection, or that the evaluation of the terms described herein is the best way to evaluate the influence of temperature changes on pressure changes. The method is proposed as a rather simple and objective technique, which seems to provide worthwhile results for use in forecasting.

3. Data selected for study

Data available to the writer limited the study to the central and eastern United States, with geographical boundaries set to include the area between latitudes 30 and 55 deg, and longitudes 68 and 100 deg (fig. 1).

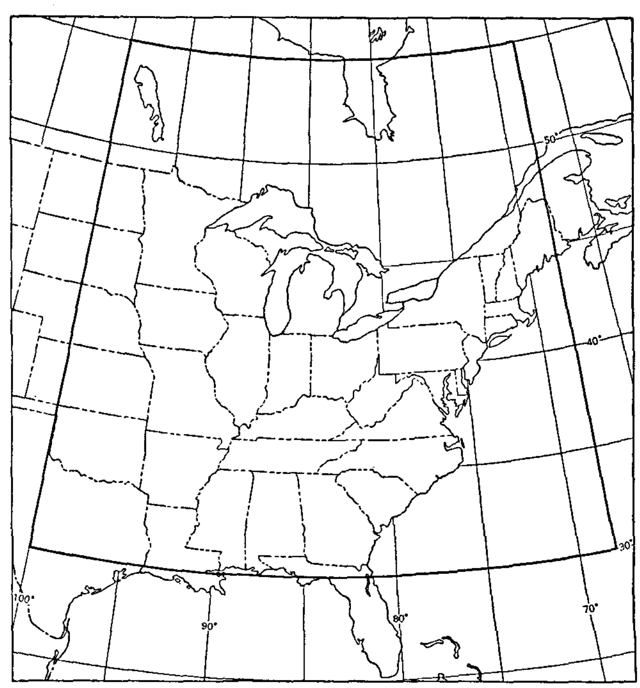

FIG. 1. Geographical boundaries of area covered by study.

Data used for the development of the forecasting system include the following months: November 1949 and 1950, December 1949 and 1950, January 1949, 1950 and 1951, February 1949, 1950 and 1951, March 1948 and 1950. Data set aside and used only for testing purposes were as follows: November 1947 and 1948, December 1947 and 1948, January 1946, 1947 and 1948, February 1946, 1947 and 1948, March 1947, 1949 and 1951.

4. Method of classification of lows

The vertical structure of low-pressure systems varies considerably from storm to storm, and within storms from day to day. Inspection of a series of weather charts will reveal that some types of disturbances cross the United States merely as troughs of low pressure, both at the surface and at most levels aloft. Other disturbances will involve closed circulations up to 850 mb, while others have closed circulations through the 700-mb level, at times reaching as high as 200 and 100 mb. The classification system used in this investigation is as follows:

Type I includes lows which have a closed circulation (3-mb isobars or 100-ft contours) at sea level and at 850 mb, but not at 700 mb;

Type II includes all lows which have a closed cir-

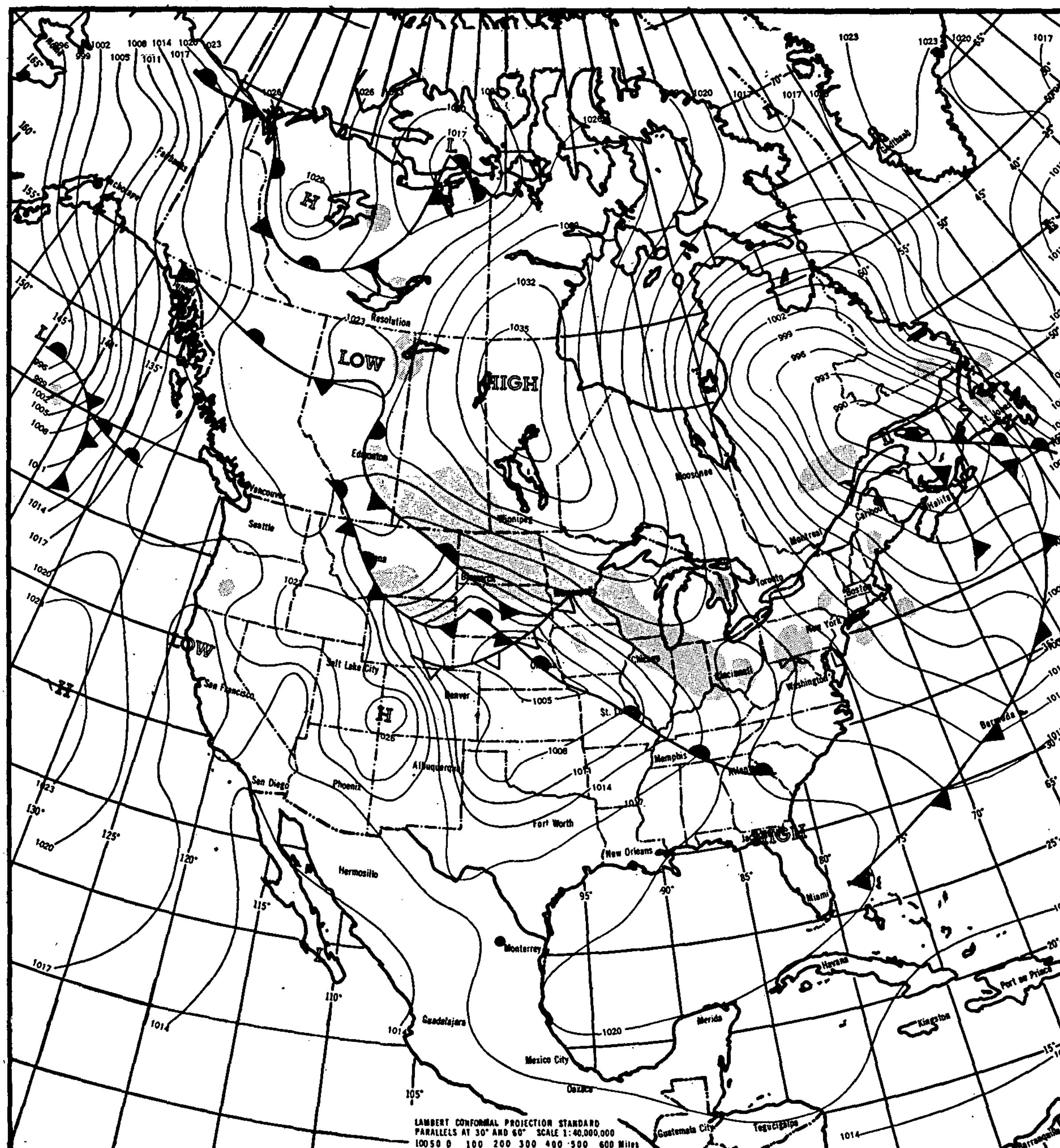

FIG. 2. Sea-level weather map; 1830 GCT 25 December 1950.

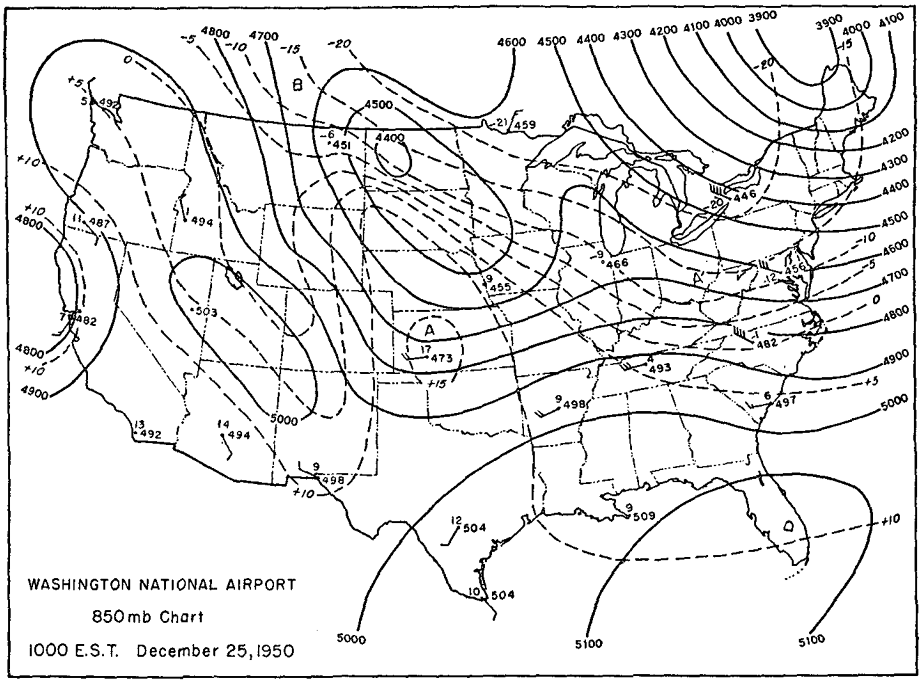

FIG. 3. 850-mb chart; 1500 GCT 25 December 1950.

culation at sea level, 850 and 700 mb, but not at 500 mb.

Thus, lows which appear on the sea-level map, but which are not closed at 850 mb, are not included. Similarly, lows which are closed at 500 mb and higher have been excluded from this investigation.

As will be shown later, the advective terms are evaluated for both 850- and 700-mb levels in type I, but only at 700 mb in type II. The steering level chosen for type I is 700 mb, while that for type II is 500 mb.

5. Type I: Evaluation of temperature advection

The method adopted to specify the temperature and motion field at 850 mb in the vicinity of the low in this type, wherein the closed circulation extends to that level but not as high as 700 mb, was to locate the first open contour-channel to the south of the closed

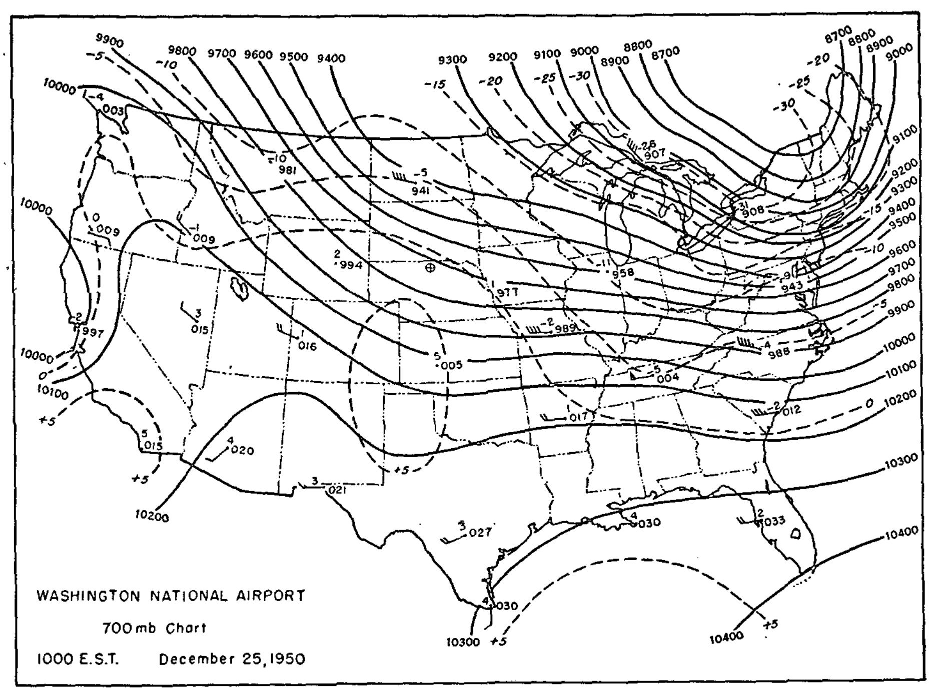

FIG. 4. 700-mb chart; 1500 GCT 25 December 1950.

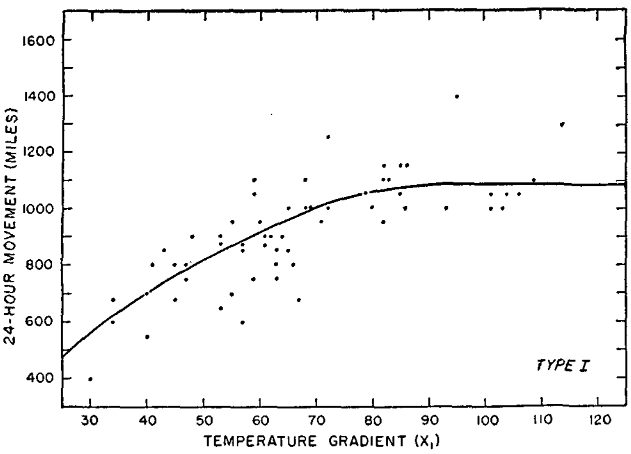

FIG. 5. Scatter diagram relating temperature term to 24-hr displacement, type I.

low center at 850 mb. The warmest region within this channel was then located, from which point a line was traced downstream through the channel to the coldest region within 1000 mi of the warmest air. A similar operation is performed upstream, to the west of the low, and the two temperature differences thus obtained are combined with the temperature difference obtained from the 700-mb chart (in the following manner), to form the primary independent variable in the forecasting of the speed of movement of the pressure system.

The position of the surface low was marked on the 700-mb chart, and similar temperature differences were obtained both upwind and downwind from this point, along the 700-mb contour channel containing this point. The two temperature differences thus obtained are then added to the two obtained at 850 mb, to form the independent variable x_1. This variable, when plotted against the subsequent 24- and 30-hr movements of the low-pressure areas in question, is shown in figs. 5 and 6. These two charts, when used in conjunction with the 700-mb steering path, may then be used to find the position of the low either 24

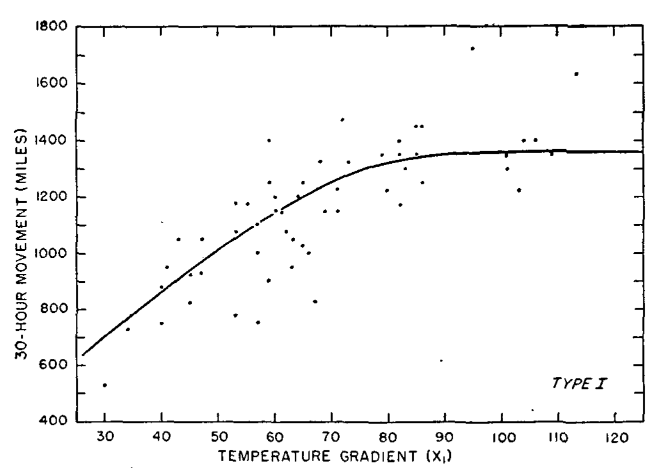

FIG. 6. Scatter diagram relating temperature term to 30-hr displacement, type I.

or 30 hr from the time of the map upon which the low appears. The 700-mb steering path is taken as that immediately above, and thence downstream from, the low.

Before proceeding to a further description of the method used for type II, we give an example of the computational procedure used in type I, covering the situation for 1830 GCT 25 December 1950 (figs. 2, 3 and 4).

At 850 mb:

1. The location of the first open 850-mb contour channel was determined to be that bounded by the 4,600- and 4,700-ft contours (see fig. 3);
2. On fig. 3, point A was determined as the location of the warmest (interpolated as 16C) air within this channel;
3. The greatest temperature difference in the downwind flow (not more than 1,000 mi from point A) is found by locating the coldest air downwind through the channel from point A. The temperature here (over southeastern Ohio) was −14C, giving a temperature difference of 30C;
4. The greatest temperature difference in the upwind flow (not more than 1,000 mi upwind from point A) is found by noting point B in Alberta, Canada, where the temperature is −14C. Thus, another 30C temperature difference is obtained. Add this to that found in step 3 (and obtain 60).

At 700 mb:

5. Mark on the 700-mb chart (fig. 4) the position of the surface low, and note the 700-mb temperature (1C);
6. From this position, determine the greatest temperature differences, both upwind (12C) and downwind (13C), but not more than 1,000 mi away in either direction, and find the total (25C);
7. Add total obtained in (6) to that in (4), (and obtain 85C);
8. Refer to figs. 5 and 6, to obtain a forecast of the 24- and 30-hr movements, respectively. From fig. 5, we obtain 1,065 mi as the total 24-hr movement; from fig. 6, 1,300 mi for the 30-hr movement.
9. The direction of movement will be parallel to that at 700 mb, directly over and ahead of the surface low. (It will be recalled that in type I we have the requirement of "open" flow at 700 mb, and that this level is thus a logical selection as the steering level.) Operating thereby on fig. 4, we find that in 24 hr the low should be located in southwestern Virginia; it should be off-shore in 30 hr. The low actually moved parallel to the 700-mb flow as forecast, for a distance of 1,100 mi in 24 hr and about 1,300 mi in 30 hr.

6. Type II: Evaluation of temperature advection

Type II lows are those having closed circulations at sea level, and 850 and 700 mb, but not at 500 mb. In this category, the 700-mb temperature advection term as herein evaluated has been found the most important. At the position of the surface low, when transferred to the 700-mb chart, we note the temperature; and from here we move both downwind and upwind, to find the greatest temperature difference to be found within 1,000 mi of the position of the low. The temperature differences are then combined, through algebraic addition. Figs. 7 and 8 show the

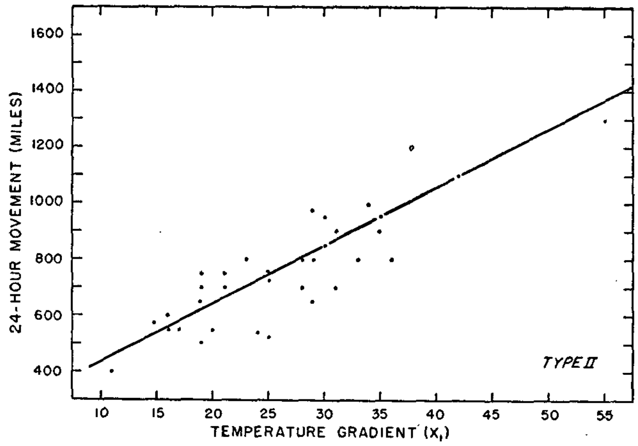

Fig. 7. Scatter diagram relating temperature term to 24-hr displacement, type II.

result obtained, when such values are plotted against the 24- and 30-hr movements of type II lows.

After fig. 7 or 8 is entered, the direction of movement is assumed to be along the 500-mb contour directly above and ahead of the position of the surface low. Note here again the choice of a steering level which is above the highest "closed" circulation.

In the case for 23 February 1950, the surface low at 1830 GCT was located at 41°N and 69°W. From this position on the 700-mb chart, we note a maximum downwind temperature difference of 15C (within 1,000 mi). A difference of 15C was also found upwind, which, when added, gave a total of 30C. Entering fig. 7, we obtain a predicted 24-hr movement of 840 mi, and fig. 8 gives 1,070 mi for 30 hr. This low actually moved 850 mi in 24 hr, and 1,075 mi in 30 hr, parallel to the flow at 500 mb.

7. Results

The average error in miles, as obtained for the two types, is shown separately in tables 1 and 2.

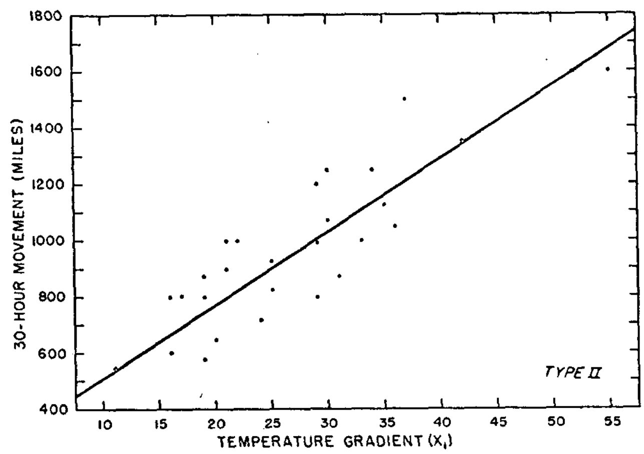

Fig. 8. Scatter diagram relating temperature term to 30-hr displacement, type II.

Table 1. Average error (miles) for type I.

	24 hours		30 hours	
	No. of cases	Average	No. of cases	Average
Basic data	63	86	56	104
Test data	16	170	14	171

Table 2. Average error (miles) for type II.

	24 hours		30 hours	
	No. of cases	Average	No. of cases	Average
Basic data	33	81	27	114
Test data	22	125	20	138

It will be noted that there is a slight increase in error from the basic to the test samples, possibly indicating that the regression lines, as fitted by eye, are not the best possible in terms of the reduction of average errors. Nevertheless, the results are considered not only to be useful, but as offering some support to the conclusions reached by Austin and Shapiro [3]. The reduction in the frequency of occurrence of both types of cases in the test data, as compared with the basic data, must be attributable to variations in weather regimes.

These results may be compared with those of Shafer [2], who reported an average error on basic data of 108 mi for 24 hr. Longley [4] related the 24-hr movement of lows to the concurrent 700-mb flow, and found the mean deviation of his estimated positions from the actually observed positions to be approximately 300 mi. Actually, Longley's results are not strictly comparable, since the error shown in the present study is the difference between the forecast distance and the actual distance of movement. However, in most cases the low moved parallel to the steering channel, and for those instances the error would be comparable to Longley's results.

A further comparison was made with a "control" forecast, made by assuming that the subsequent 24- and 30-hr movements would be at the same average speed as that for the past 6 hr. Results obtained with this type of pure extrapolation, when applied to the test cases, are summarized in table 3.

Table 3. Average error (miles) using extrapolation of past 6-hr speed of movement.

	Type I		Type II	
	No. of cases	Average	No. of cases	Average
24 hours	16	333	22	197
30 hours	14	435	20	200

8. Conclusions

Though the problem of forecasting lows with a closed circulation up to as high as 500 mb or higher has not been treated herein, it is believed that these results point not only to a successful stratification device for finding an appropriate steering current for lows, but that this device provides a means for a reasonably accurate approximation of thermal advection influences on pressure changes.

Acknowledgments.—The writer wishes to extend his thanks to Mr. R. C. Schmidt and Mr. Conrad P. Mook for their suggestions and help in the preparation of this paper.

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