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IMPROVEMENT OF TREND METHODS OF FORECASTING

by

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In a rather extensive report on the trend method of forecasting,(1) it was explained that the basis of the method involves the construction and extrapolation of mean trend graphs at each of several intersections of latitude and longitude, and that the latest daily pressure values may be used to supplement the mean pressures in the process of extrapolating these mean barograms. The use of the latest daily values as an indication of the trend in the mean barogram is, at least for higher level charts, justified because of the extremely high correlation found between the daily pressures and the means of which they are the middle values. (2) However, experience in the construction of mean barograms for the three-kilometer chart indicates that in spite of the high correlation, the latest daily pressure values are at times so far in error that they fail completely to give an indication of the correct trends. Thus, while errors of 2 millibars or less are the most frequent ones, they at times exceed 5 millibars, and occasionally reach as high as 10 to 15 millibars, particularly at higher latitudes. Therefore, it seems obvious that a simple way of correcting the mean barograms, and therefore the prognostic trend charts, is to find methods of improving the estimate of the mean pressures based on the middle daily values.

The following report contains the results of an attempt to find and apply such methods in the construction of prognostic mean three-kilometer charts. The first method that suggests itself is based on the observation that high daily pressure values tend to be higher than the corresponding mean values, while low daily pressures tend to be lower. This is due to the well-known statistical fact that the variability of a mean will be less than that of the individual values going to make up the mean. When departures from normal of the daily pressures are plotted against departures from normal of the corresponding means, it is found that a departure of 10 millibars in the daily values is associated on the average with a departure of only 7 millibars in the mean values. If the daily pressures are taken from points which happen to lie at a trough or a ridge, the differences may be even greater, depending on how pronunced the trough or ridge is and how far the departures of pressure are from normal.

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1. Clapp, P. F., and Namias, Jerome, Use of Trend Methods in Forecasting Five-Day Mean Pressure Charts. United States Weather Bureau Five-Day Section, November, 1942.

2. See Page 3 of Reference (1).

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Another way to improve the estimate of the mean is based on the recognition that in using the middle daily value alone the forecaster is not making full use of all the available data which goes to make up the mean. Thus, the latest daily pressure at a given intersection corresponds to the mean of the five-day series which begins two days before and ends two days later. Therefore, three of the five daily pressure values, including the latest daily value, are available to the forecaster, and an estimate of the fourth can be obtained from the twenty-four hour progostic three-kilometer chart which is madeevery day as a part of the regular routine.

Three different methods for estimating the mean value, using this additional information, were devised.

The first method, called the "trough and ridge" method, makes use of the observed fact, mentioned before, that the variability of the daily pressure values is greater than that of the mean, particularly when the daily values lie on a trough or ridge. This principle can be explained quite simply in the following ideal case. Let us suppose that the daily pressure waves at three kilometers are sinusoidal, and move from west to east at a constant rate, without deepening or filling. Then the pressure changes at a fixed point will also be sinusoidal, and because of the symmestry of the resulting pressure oscillations, it can be shown very simply that the mean pressure ($\bar{P}$) corresponding to a daily pressure (P_3) lying on a trough or a ridge is given by the formula:

$$(1)\ \bar{P} = \frac{2P_1 + 2P_2 + P_3}{5}$$

where $\bar{P}$ is the mean of the 5 daily pressures P_1, P_2, P_3, P_4, and P_5,

On the other hand, when the daily pressure value lies on an inflection point of the pressure wave, the corresponding mean pressure is simply:

$$(2)\ \bar{P} = P_3$$

It will be seen from formula (1) that since P_1 and P_2 are, in this simple case, almost invariably less than P_3. The amount of the difference depends on the "sharpness" of the ridge. Thus it will be seen that, in this simple case of sinusoidal waves, the greater variability of the daily values is due to points lying on troughs or ridges. If we assume that these simple conditions hold true in the atmosphere, then we may use formulae (1) or (2) to estimate the mean pressures. This has been adopted as Method 1.

The second method makes use of the multiple regression between $\bar{P}$, as the dependent variable, and P_1, P_2, and P_3 as independent variables. In other words, the mean pressure is assumed to be a linear function of the first three daily pressure values. The regression equation for the fall season, and for the standard intersection 45N, 85W, is:

$$(3)\quad \frac{\bar{P} + P_1 + P_2 + 2.27\,P_3 - 1.97}{5}$$

where the pressures are expressed as departures from 700 millibars.

The third method expresses the mean pressure simply as the arithmetic mean of the first three daily pressure values plus the estimate of the fourth value based on the prognostic daily three-kilometer chart. The fifth daily pressure is assumed to be the same as that obtained from the prognostic chart. Thus we have:

$$(4)\quad \frac{\bar{P} = P_1 + P_2 + P_3 + P_d + P_d}{5}$$

where the terms are the same as before except that P_d is the estimated pressure value obtained from the prognostic chart.

Each of these three methods were used to estimate the mean pressure at three different intersections for a series of thirty mean three-kilometer maps from the fall season of 1942. The results were then compared to those for the original method, which makes use of the middle daily value alone. The mean errors, without regard to sign, for the different methods and for the intersection 45N, 85W are given below

Estimate Based on	Middle Daily Value (P_3)	Method 1	Method 2	Method 3
Average Error	3.233	2.700	2.400	2.100

An exact statistical test shows that the new methods result in a significant improvement over the original method. The one showing the least error is Method 3. The apparently small improvement indicated for this method (Table 1) tends to mask the fact that large errors are actually reduced considerably. Thus, errors in the middle daily value of 5 millibars or more (averaging 6.6 millibars) are reduced to 3.1 millibars, on the average. On the other hand, errors of 2 millibars or less (averaging 0.93 millibars) are increased to 1.6 millibars. The small improvement when all errors are taken together is due to the fact that errors of less than 2 millibars comprise fifty per cent of the observations while those of more than 5 millibars comprise only thirty-three per cent of the observations.

It is interesting to note that Method I reduces the errors considerably when the points lie on pronounced troughs and ridges. In fact, the improvement is often greater than that obtained using Method 3, However, since the estimate based on Method 1 results in no improvement for pressures lying on inflection points, and since some of these pressures are badly in error, the net improvement is not as great as for Method 3.

Since the application of Method 3 necessitates a rather lengthy addition to the normal routine of preparing prognostic trend charts, the question naturally arises as to whether the resulting improvement in the trend charts themselves justifies the additional work. To test this, trend graphs were constructed for a winter month making use of the improved method, (Method 3) of estimating the mean pressure corresponding to the latest daily value, and from these graphs nine half week and nine full week trend charts were made. These were then compared in four different ways with the original trend charts made by the simpler method.

All these methods of comparison indicated that on the whole the new method produced results, in this case, which certainly were not better, and perhaps were a little worse than the old method. The reasons for this rather disappointing result are not obvious, but there aretwo which seem rather outstanding.

In the first place, considering the map as a whole rather than one particular point, it is probably true that large errors in the estimate of the mean corresponding to the latest daily value are so rare that application of the new method cannot appreciably improve the net results of the extrapolations. Thus, in the case of the above tests, it was found that only nineteen per cent of the errors were 5 millibars or more, and fifty-five per cent were 2 millibars or less. However, the frequency of large errors increases for points at higher latitudes, and therefore we might expect to find more net improvement at higher latitudes. It is interesting to note that otherwise the results are about the same as these discussed before. The average error was about 3 millibars for the simple method and 2 millibars for the improved method. Errors over 5 millibars (averaging 6.9 millibars) dropped to 1.7 millibars, while those less than 2 millibars (averaging 1.1 millibars) increased to 1.6 millibars.

The second principal reason for the failure of the experiment is probably due to the difficulties in extrapolating the mean barograms beyond the limit of available data. Errors made in this part of the extrapolation curve are often so large that they tend to mask the slight improvements that may result from better use of available data.

Thus, it may be concluded that the additional labor of application is too great to justify the use of the more complicated method in a direct quantitive manner. However, two qualitative applications are currently used in extending the mean barograms. If the latest daily pressures are much above or much below normal, then they are adjusted downward or upward by 3 or 4 millibars. If, at the same time, the points lie on ridges or troughs, an even greater

adjustment is made. Thus, a daily pressure value which is 10 millibars or so above normal and which is located on a ridge may be lowered 5 to 15 millibars depending on the "sharpness" of the ridge. Similar adjustments are made for points lying in the vicinity of troughs.

Verification of Prognostic Pressure Charts

Two of the ways that were used for comparing the prognostic charts prepared by the two different methods will be discussed briefly below, since they give some indication of the value of the trend charts. One of these methods involves the correlation of observed with prognostic pressure patterns using twenty-three points within the United States. (3)

The other method involves the correlation of the prognostic pressure changes from map to map with the observed pressure changes for the same twenty-three points. These correlations were computed for both sets of prognostic charts as a basis for comparing these charts. We wish to discuss here, however, only the correlations computed for the trend charts made by the original method. These correlations are shown in Table 2. Columns 1 and 3 contain the correlations between observed and prognostic pressure patterns while columns 2 and 4 contain the correlations between observed and prognostic pressure changes. It may be pointed out here that neither method of correlation is entirely satisfactory as a basis for verifying prognostic pressure patterns. Thus, the method of correlating the pressure patterns directly is objectionable because of the fact that some of the correlation is due to the tendency of many of the pressure patterns to resemble the normal pattern. Thus, if one were to correlate two maps picked at random, the correlation would probably not be zero, due to the influence of the normal pattern. In order to avoid this "fictitious" result, we may either correlate the departures of the pressures from the normal pattern(4), or we may correlate the change in pressure from one map to the next. The first method suffers from the objection that if both the prognostic and observed patterns resemble the normal, then even in the case of very close agreement the correlation may be zero. In other words, a forecast may be considered as worthless solely because of the fact that it resembles the normal pattern. The second method suffers from a similar objection. If the observed change in pressure from one map to the next

(3) For an explanation of the method used, see the reference given on page 3 of the original report. In the case described in the present report the pressures themselves were used in the correlation rather than their departures from normal.

(4) See Reference (3)

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is uniform over the entire map, meaning that one map has a pattern very similar to the preceding one, then the correlation may also be low in spite of the fact that the real errors in pressure change are very small. This tendency is soon in the following table in the marked variability of the change correlations in columns 2 and 4 as opposed to the fairly constant values in Columns 1 and 3.

Table 2.

Half Week			Full Week		
Date (1943)	1 Pressure Correlation	2 Change Correlation	Date (1943)	3 Pressure Correlation	4 Change Correlation
January 30-Feb. 3	.97	.82	Feb.3-7	.88	.62
Feb. 3-7	.97	.56	Feb.6-10	.92	.10
Feb. 6-10	.96	.56	Feb. 10-14	.70	.22
Feb. 10-14	.87	.51	Feb. 13-17	.73	.08
Feb. 13-17	.98	.82	Feb. 17-21	.88	.63
Feb. 17-21	.94	.86	Feb. 20-24	.75	.79
Feb. 20-24	.95	.60	Feb. 24-28	.88	.44
Feb. 24-28	.94	.57	Feb. 27-Mar.3	.86	-.08
Feb. 27-Mar.3	.99	.67	Mar. 3-7	.95	.64