# VERIFYING THE 72-HOUR 500MB FORECAST MAP

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## ABSTRACT

Forecast meteorologists are regularly called upon to furnish information on weather for three or more days into the future. One source of guidance available to the forecaster is numerical model output. The following paper presents results of a study designed to test the effectiveness of one product -- the 72-h, 500mb forecast map. Results emphasize usefulness of this product and suggest how best to interpret its message.

## 1. INTRODUCTION

Since mid-1966, the National Meteorological Center (NMC) has routinely produced several computer generated forecast maps based on a baroclinic "primitive equation" representation of the atmosphere as described by Shuman and Hovermale (1). This depiction is commonly called the PE model. Among the PE output are United States centered maps, forecasting the height of the 500mb pressure surface at various times over approximately one quarter of the globe. For forecasts beyond two days, a barotropic extension of the 48-h PE is utilized. This study is concerned with the performance of the 72-h 500mb forecast and particularly its applicability over the south-central plains.

On the 72-h forecast map, the height field is displayed via contour lines at intervals of 60m. Since the height of a column of air is directly related to the pressure, patterns of large-scale height oscillations can be interpreted as pressure troughs and ridges. As most forecasters are aware, the global pressure pattern and its movement are important in long-term prediction, since decreasing pressure is generally associated with regions of mild upward motion where precipitation probabilities are highest.

The height gradient on the forecast map implies the geostrophic wind. Thus, the 72-h prognosis yields information concerning the expected direction and strength of the flow aloft. This in turn furnishes the forecaster with an estimate of expected extratropical cyclone movement (usually parallel to the strongest wind bands aloft). Furthermore, the most intense thunderstorms are often associated with regions of strong winds aloft (2), and geostrophic wind forecasts are important in this regard.

The authors have attempted to devise forecaster oriented tests to determine the usefulness of the 72-h prognosis or "prog" -- its strengths and weaknesses, its patterns of error and its overall value as a prognostic tool, especially in the south-central plains.

## 2. DATA AND ANALYSIS

Maps of the 72-h forecast 500mb analysis and National radar summary were received from the NMC via the National Facsimile (NAFAX) circuit. Severe weather events were obtained from the severe storm log of the National Severe Storms Forecast Center and supplemented (when appropriate) by the more detailed data of the National Severe Storms Laboratory (NSSL) for events in and near Oklahoma. GOES satellite data were used to distinguish between clear and cloudy sky conditions and to supplement precipitation information.

Testing covered the period from 3 April though 10 June 1979. 72-h forecasts are available from both 1200Z and 0000Z data. However, only the 1200Z base data were evaluated, since this is the map used most often at NSSL in furnishing long-range guidance to researchers collecting data on severe local storms. Several tests were performed on the data to evaluate the usefulness of the forecast. Whenever possible a Critical Success Index, or CSI (3), was computed for test results. This deceptively simple index provides prognosticators with a single number representing a combined evaluation of those factors most important to a "successful" forecast; namely, the probability of detecting an event and the false alarm rate created in the attempt. Briefly stated: if x is the number of events correctly predicted, y the number of events not predicted, and z the number of events predicted which did not occur, then the probability of detection POD = $x/(x+y)$, the false alarm rate FAR = $z/(x+z)$, and the CSI = $x/(x+y+z)$. The following paragraphs describe these tests and a few of the results.

a. Southwesterly flow aloft

In the long term it has been noted that rain showers, thunderstorms and indeed most precipitation events over the south-central plains occur in conjunction with southwesterly flow aloft. This observation seems dynamically sound since southwesterly flow generally occurs only on the eastern, or leading, edge of long-wave troughs where the large-scale flow is ascending. For example, in Oklahoma during the test period, 92 percent of all severe weather occurred in southwesterly flow. Thus, if one were to use southwesterly flow as the single criterion for a forecast of severe weather, the POD would be 0.92. However, 62 percent of the southwesterly flow days did not produce severe thunderstorms (i.e., the FAR = 0.62). The success of the technique, as measured by the CSI, was 37 percent. Nevertheless, the fact that 92 percent of the severe weather occurred in southwesterly flow suggests that it would be useful to know the upper flow pattern in advance.

The first test conducted on the 72-h data, therefore, dealt with its ability to forecast southwesterly flow. In the 59 cases for which verification data were available it was found that POD = 0.83, FAR = 0.27, and CSI = 0.63. An overall "success" of nearly 65 percent is considered about average on a three-day forecast.

b. Strength of upper flow

An empirical "rule of thumb," used occasionally when better data are not available, is that a 500mb height contour interval (60m) equal to the N-S width of Oklahoma (350km) yields a geostrophic wind of about 35kt. Since this is a convenient length, it was arbitrarily decided to categorize height gradients relative to this distance. Tighter gradients were classified as "strong," looser gradients as "weak." On this basis, the 72-h forecasts of "strong" flow aloft produced the following statistics; POD = 0.83, FAR = 0.34, and CSI = 0.58, or an overall success of nearly 60 percent.

c. Long-wave trough and ridge position

Many forecasters use the 72-h map for determining the position of long-wave troughs and ridges. This information, if accurate, furnishes a scenario of the approaching weather trend. However, these long-wave features are often vague, since shorter wave length disturbances can mask the actual configuration of the global pattern. Designing a test for long-wave positioning is, thus, quite difficult, particularly without the original objectively analyzed data being available.

In order to arrive at some meaningful determination regarding the product's ability to forecast in this category, the following test was conducted. At

10 degrees longitude intervals between 50 degrees west and 160 degrees west, a "mean height" was computed from the 500mb analyses by averaging the heights at 30 degrees, 40 degrees, 50 degrees and 60 degrees north latitude. Relative minima were called "troughs", maxima labeled "ridges." Results were then plotted on a graph of "date versus longitude" and a fitted curve adapted to the points (circles, Fig. 1). The fitted curves were assumed to represent various long wave features. Similarly, "trough" and "ridge" positions were determined from the 72-h forecast map. Results were plotted on the same charts as the actual data (x's, Fig. 1).

Though only April data are illustrated here, graphs were constructed for the entire test period. Subjective study of Fig. 1 reveals good correspondence between forecast and actual positions. This agreement holds true for May and early June as well. Numerical differences averaged less than 10 degrees longitude for both troughs and ridges. Thus, it seems that the 72-h prog handles long-wave trough and ridge positions very well. The primary difficulty in this category from a user standpoint would be the identification and interpretation of the long-wave features on a day-to-day basis.

d. Observed vs. forecast height values

Since the strength of vertical motions depends on the amplitude of troughs and ridges, the accuracy of the absolute 500mb height forecasts was tested next. A sampling area which ran from 70 degrees to 140 degrees west longitude and from 30 degrees to 50 degrees north latitude (i.e., the United States and surrounding waters) was chosen. A representative height at each 10 degrees longitude was determined by computing an average of the heights at 30 degrees, 40 degrees and 50 degrees latitude. The averages were calculated from both the forecast and the verification maps. The actual height was then subtracted from the

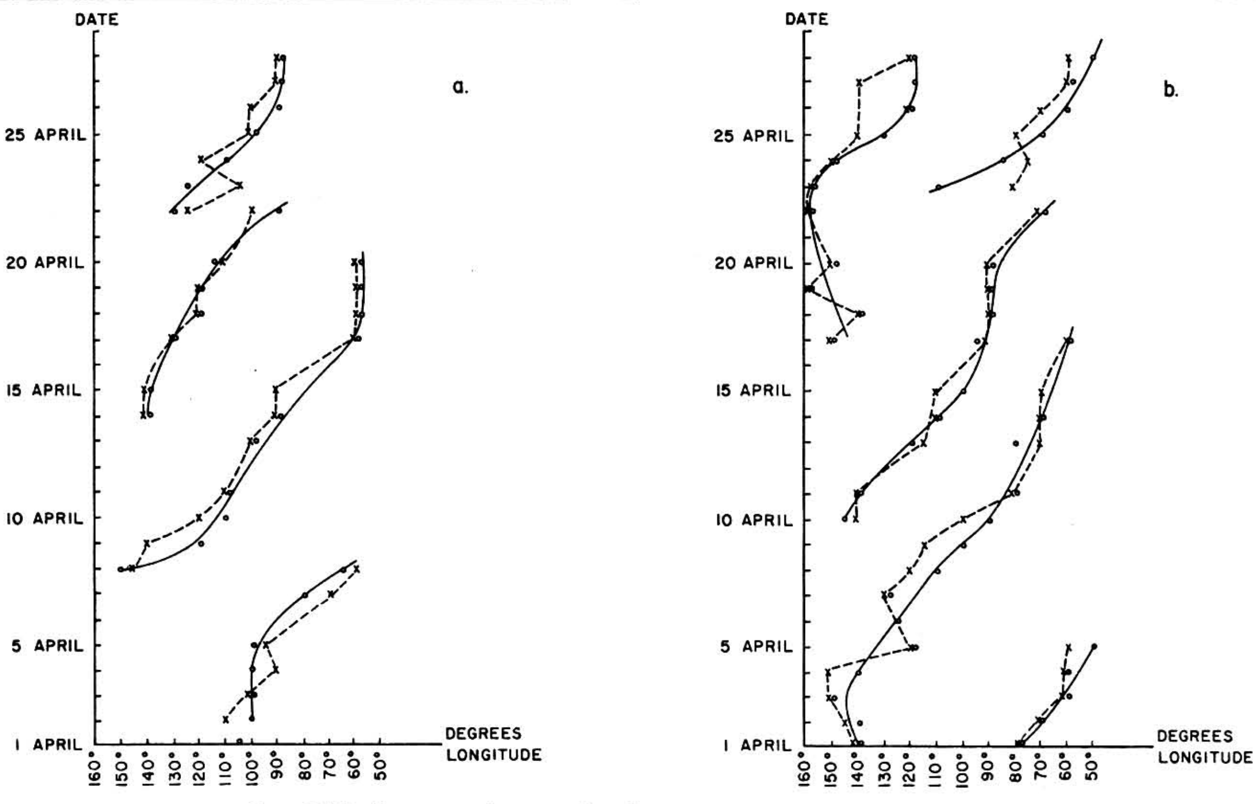


Fig. 1. a) Actual 500mb estimated long-wave trough positions vs 72-h forecast. Circles and solid lines are actual; x's are forecast. b) Same as "a" except ridge positions are shown.

forecast height and graphs were constructed as in Fig. 2 for each of the eight longitudes.

Results showed that forecast heights were too high 72 percent of the time, too low 25 percent of the time and were correct (to plus or minus 10m) in only 3 percent of the cases. Many of the "high" forecasts were 100m or more too high, while "under-forecasts" were rarely more than 70m too low. Thus, the most common error in height forecasts by the prognosis was a significant overstatement. The average height difference (forecast value minus actual) was, by longitude, +29m (140 degrees), +25m (130 degrees), +20m (120 degrees), +11m (110 degrees), +11m (100 degrees), +28m (90 degrees), +40m (80 degrees) and +41 (70 degrees).

e. Other features

A very critical error was noted. The 72-h prog often tended to forecast much shallower troughs entering the west coast than those actually observed. The same tendency has been noted in past years as well. This underforecasting tendency is evidently due to the lack of critical observations over the data-sparse Pacific, where a small but intense jet maximum might easily be missed at observation time. Often the result is that major weather systems remain severely understated until they are well on shore. Precipitation forecasts for the west coast suffer as do the three-day outlooks for severe weather on the plains.

Another feature noted is that the prognosis appears to remain plagued by the "locked-in" error; i.e., the opening up and ejecting of 500mb closed lows is retarded by the model. In several cases this spring, the "72" predicted an intense eastward moving closed 500mb low, when in fact a weakening northeastward moving ystem occurred (e.g., 13 April 1979).

3. SUMMARY

Regarding the performance of the 72-h 500mb PE forecast:

a. The product seems to handle long wave trough and ridge positioning very well,

b. Heights on the average are too high and, in particular, strong disturbances tend to be significantly underplayed as they enter the west coast,

c. 500mb closed lows over the United States may become "locked-in" and fail to weaken and/or lift out when appropriate, and

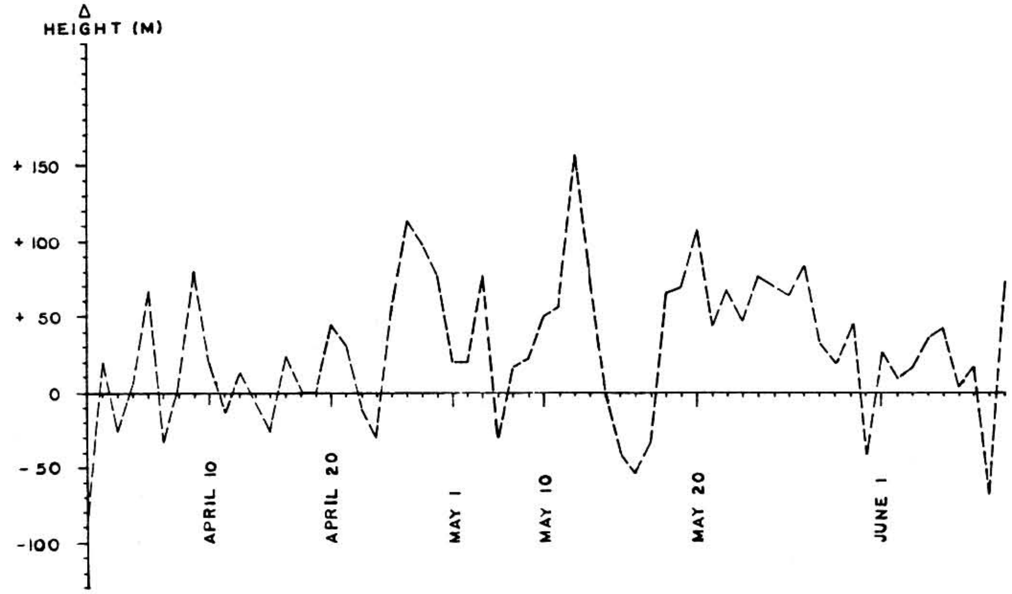


Fig. 2. Example of the daily 500mb height deviation (forecast minus actual) in meters. Sample is for 90 degrees west longitude.

d. Specific forecast information regarding the direction and speed of 500mb flow over Oklahoma can be ascertained with a 60-65 percent accuracy using the "72". This type of information is important since more than 90 percent of the severe weather in the south-central plains this spring occurred in southwesterly flow aloft.

Although the "72" has a certain reliability in many aspects, the data point out a critical need for the NMC to more effectively incorporate into the 500mb PE models the abundant 250mb aircraft data over the Pacific Ocean as well as satellite derived upper tropospheric information. It seems evident that current techniques for interpolating 250mb data down to 500mb are not satisfactory for defining shorter waves at 500mb. It appears that the interpolated amplitudes are generally too small, then decreased even further by numerical smoothing. The need for proper definition of weather systems while they are still over the Pacific cannot be overemphasized. Secondly, it was found that the "72" had a certain reliability in many aspects, and we felt that line forecasters that do not know this might want to. Finally, by publishing these results in a forecasting oriented journal, it is hoped that other forecasters might present their evaluations of other commonly used NMC forecast products.

REFERENCES AND FOOTNOTES

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