Specification of Monthly Mean Surface Temperatures from 700-mb Heights

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ABSTRACT

Multiple regression equations relating surface temperature to the mid-tropospheric circulation pattern are tested on observed 30-day mean 700-mb heights. The equations are found to specify monthly mean temperatures within one class out of five about 90 per cent of the time. This is better than results obtained by use of 5-day mean data from which the equations were originally derived.

In the appendix to a previous paper in the *Journal of Meteorology* (Klein, Lewis and Enger, 1959), it was pointed out that multiple regression equations, which had been derived for prediction of 5-day mean temperatures from 5-day mean 700-mb heights observed two days earlier, could be applied with even better results to specification of 30-day mean temperatures from the field of simultaneous 30-day mean 700-mb height. It may be objected, however, that the results upon which this conclusion is based were not drawn from a completely independent sample, since the test period (56 winter months from December 1945 to March 1958) partly overlapped the period from which the original equations were derived (140 five-day periods from December 1947 to March 1957). Additional tests have therefore been made with later data and the results, to be presented in this note, completely support the original conclusion.

In the original paper only the winter season was discussed. Since its publication, separate prediction equations have been derived for the other seasons, using the screening method described in Klein, Lewis and Enger (1959) and the basic 5-day mean data described in Klein et al. (1960). The results for spring and fall were similar to those for winter; an average of 55 per cent of the variance of surface temperature in the developmental sample could be explained by 700-mb height alone, using from 2 to 6 selected points in the vicinity of North America as predictors for each city. During summer, however, the predominance of local effects permitted only 45 per cent of the temperature variance to be explained by the multiple regression equations.

With the aid of an electronic computer, these prediction equations have been applied on a routine basis since September 1959 to observed 30-day mean 700-mb heights computed about the 15th and 30th of each month in the Extended Forecast Branch of the United States Weather Bureau. The resulting objective specifications of 30-day mean surface temperature have been verified at 39 cities scattered across the contiguous United States twice a month through June 1961 in terms of the 5 classes customarily used in extended forecasting (U. S. Weather Bureau, 1961; Naimias, 1953). A typical temperature estimate and its corresponding observed map are illustrated in Fig. 1, and the verifications are summarized by season in Table 1.

<table>
<thead>
<tr>
<th>Line</th>
<th>Season</th>
<th>Years</th>
<th>No. of cases</th>
<th>Per cent correct</th>
<th>Per cent within 1 class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fall</td>
<td>1950–60</td>
<td>11</td>
<td>49.9</td>
<td>89.1</td>
</tr>
<tr>
<td>2</td>
<td>Winter</td>
<td>1960–61</td>
<td>13</td>
<td>48.6</td>
<td>92.6</td>
</tr>
<tr>
<td>3</td>
<td>Spring</td>
<td>1960–61</td>
<td>12</td>
<td>39.2</td>
<td>88.0</td>
</tr>
<tr>
<td>4</td>
<td>Summer</td>
<td>1960</td>
<td>6</td>
<td>39.0</td>
<td>84.6</td>
</tr>
<tr>
<td>5</td>
<td>Winter</td>
<td>1953–58</td>
<td>27</td>
<td>46.0</td>
<td>90.7</td>
</tr>
<tr>
<td>6</td>
<td>Winter</td>
<td>1948–58</td>
<td>40</td>
<td>39.6</td>
<td>81.9</td>
</tr>
</tbody>
</table>

(5-day data)

Table 1 shows that during the 2-yr test period from 1959 to 1961 the temperature specifications were most accurate during winter and fall and least accurate, as expected, during summer. For fall, winter and spring, combined, the 30-day mean temperature was estimated in exactly the observed class 46 per cent of the time and within one class of the observed 90 per cent of the time. These scores are considerably higher than those expected by chance or by persistence (U. S. Weather

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1 A typical prediction equation is given in Eq (3) of Klein, Lewis and Enger (1959).
Fig. 1. Specified and observed departures from normal of mean surface temperature for the 30-day period from mid-April to mid-May 1961. Analysis is in terms of the five temperature classes customarily used in the U. S. Weather Bureau. (A) is the objective estimate, (B) is the verifying map. This specification had about average skill, with 48 per cent in the correct class and 90 per cent within one class.
Bureau, 1961) and show the importance of the mean 700-mb circulation in indicating the month's average temperature (Namias, 1953).

For purposes of comparison, the last 2 lines of Table 1 present some results for earlier periods which partly overlap the original developmental sample. In these tests surface temperature classes were estimated at a grid of 100 points from concurrent observed 700-mb heights by applying the equations derived for the winter season (Klein, Lewis and Enger, 1959). Use of 30-day mean data for 27 months from January 1953 to December 1958 (line 5) gave nearly the same results as those obtained in the two winters of completely independent data (line 2). On the other hand, considerably poorer scores were obtained by specifying 5-day mean temperatures from 5-day mean heights (line 6) during 40 cases chosen at random as part of another experiment (Gilman, 1960), despite the fact that the equations were originally derived from 5-day data. These results support the conclusion (Klein, Lewis and Enger, 1959) that averaging over a longer time period improves the relation between temperature and circulation, probably by smoothing the effects of small-scale and short-period phenomena.

Improved results could be obtained if the prediction equations were rederived by eliminating the 2-day lag between temperature and height and by using 30-day instead of 5-day mean data. Fig. 5 of Klein, Lewis and Enger (1959) suggests that this procedure would lead to increased importance of the local 700-mb height (in the vicinity of the station) at the expense of the remote point (half a wave length upstream). However, the improvement obtained through rederivation would probably be small, and perfect specification would require many additional parameters, such as sea-level pressure, snow cover, sea surface temperature, cloudiness, and soil moisture (Namias, 1961; Dunn, 1960).

In conclusion, it should be emphasized that this paper has been limited to the concurrent relation between temperature and circulation and has not treated the problem of prediction as such. It has been demonstrated that a given pattern of upper level height can be objectively translated into a corresponding mean surface temperature pattern with considerable accuracy by means of linear multiple regression equations. These equations may therefore serve as valuable research tools in a wide variety of studies dealing with such topics as climatic change, the general circulation, and long range forecasting. Moreover, the equations can also be used directly in prediction by applying them to various prognostic charts of the 700-mb height field (as is done routinely in the Extended Forecast Branch of the Weather Bureau). To a large extent, however, the accuracy of the resulting temperature forecasts depends on the accuracy of the height forecasts upon which they are based. The basic problem of predicting the monthly mean circulation pattern has been discussed at length elsewhere (Namias, 1953) and is not within the scope of this short contribution.

REFERENCES


Klein, W. B., B. M. Lewis and I. Enger, 1959: Objective prediction of five-day mean temperatures during winter. J. Meteor., 16, 672–682.

