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DEVELOPMENT OF LFM-BASED MOS TEMPERATURE FORECAST EQUATIONS FOR ALASKA

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1. INTRODUCTION

In 1975, the Techniques Development Laboratory used the Model Output Statistics (MOS) approach (Glahn and Lowry, 1972) to develop calendar day maximum/minimum temperature (max/min) forecast equations for Alaska (Hanas, 1975). Forecasts of the max/min were available for the 14 stations shown in Table 1. From 0000 GMT model data, the calendar day temperature guidance was valid for the day 1 (today) max, the day 2 (tomorrow) min and max, and the day 3 (day after tomorrow) min. Under normal climatic conditions, these values verified approximately 24, 36, 48, and 60 hours, respectively, after 0000 GMT. Similarly, at 1200 GMT, forecasts were produced for the day 2 (tomorrow) min and max, and the day 3 (day after tomorrow) min and max. For normal diurnal changes, these forecasts were valid approximately 24, 36, 48, and 60 hours, respectively, after 1200 GMT. In this initial development, the forecast equations were derived from coarse-mesh primitive equation (PE) model (Shuman and Hovermale, 1968) data that were stratified into two 6-month seasons: cool (October-March) and warm (April-September). Several years later, the Alaskan max/min forecast equations were rederived (Dallavalle, 1979) with the model data being stratified into 3-month seasons: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). While the new equations were more accurate than the original ones, the guidance was still based on PE model output.

In August 1980, the PE model was replaced by a spectral prediction model (Sela, 1980; National Weather Service, 1980). Preliminary testing of the Alaskan MOS temperature equations (Stackpole, 1980) indicated that the accuracy of the max/min forecasts significantly declined when spectral model fields were used as input to the MOS equations in place of PE model variables. In the conterminous United States, a similar deterioration in skill caused the PE-based MOS temperature guidance to be discontinued in December 1980. However, max/min forecasts based on the Limited-area Fine Mesh (LFM) model (Newell and Deaven, 1981; National Weather Service, 1978) were available for stations in the conterminous United States and were, in fact, considered to be more accurate (Schwartz et al., 1981). For Alaska, though, no alternate forecasts were available, so spectral model fields were applied to PE-derived equations.

On September 29, 1982, we began using LFM-derived max/min equations for Alaskan stations. In this paper, we describe the development of the new equations after various experiments showed forecasts based on LFM equations were more accurate than those made from PE-derived relationships. As part of the new guidance package, predictions of the surface temperature at 6-h intervals from 12 to 54 hours after initial model time (0000 or 1200 GMT) are also produced and disseminated for 38 Alaskan stations.

2. THEORY

In the MOS approach to objective weather prediction, equations are developed with a statistical method that relates various surface weather observations (predictands) to the forecasts from particular numerical weather prediction models (predictors). Surface observations and various climatic terms are often included as possible predictors. The statistical equations that result from this procedure account for physical relationships between the model fields and the surface weather, as well as systematic errors in the dynamical model. In an operational environment, the numerical model fields are used in the statistical prediction equations to produce forecasts of weather elements. Clearly, however, if the original systematic biases in the dynamical model disappear or if the numerical model itself is replaced by a different version, the guidance produced by the MOS equations likely will deteriorate in quality.

For the temperature equations, predictand data (max, min, or the temperature at a specific hour) are correlated with various combinations of predictor data (LFM model fields, surface observations, and climatic terms). The statistical relationships between the predictand and predictors are established by use of a linear forward selection regression technique. The multiple regression equation to predict the temperature, $\hat{T}$, is of the form:

$$\hat{T} = a_0 + a_1 X_1 + a_2 X_2 + \ldots + a_k X_k,$$

where $\hat{T}$ is the forecast value, a_0 is the regression constant, a_i are the regression coefficients (i=1,2,...,k terms in the equation), and the X_i are the predictors selected by the regression procedure. The first predictor chosen in the equation is the one that is most highly correlated with the predictand. Subsequent predictors are selected on the basis of producing the highest reduction of variance when combined with terms already in the equation. In the development of temperature equations, the screening process is stopped when a certain number of terms are selected (either a maximum of 10 or 12) or when none of the remaining unselected predictors contributes at least 0.25% to the total reduction of variance. Before the statistical screening is done, the LFM model fields are interpolated (after smoothing, if necessary) to the station of interest. For stations near the outer boundary of the LFM model grid, a bi-linear interpolation scheme is used. For all other sites, a bi-quadratic interpolation technique provides the station values. Each equation developed applies only to a single station. By dividing the developmental data into smaller subsets, we are able to derive forecast equations for each predictand, each station, separate seasons, distinct projections, and each forecast cycle (0000 or 1200 GMT).

Later in this paper, we discuss the simultaneous derivation of temperature equations. In this manner, MOS equations are developed at the same time for several different predictands. The first predictor chosen by the regression process is the variable that produces the greatest reduction of variance for any one of the predictands. Subsequent equation terms are selected according to the predictor that produces the greatest reduction in variance for any predictand when combined with other predictors already in the equations. Once a predictor is selected, the term is incorporated into the equation for each predictand and the coefficient is adjusted accordingly. As a result of a simultaneous derivation, the same predictors are used in the equations for all predictands, but the coefficients are different. We've found in previous work (Dallavalle et al., 1980) that this method enhances, but does not guarantee, consistency in the objective temperature forecasts.

3. PREDICTORS AND PREDICTANDS

In accordance with a request from the Alaskan Region, we divided our developmental data into four seasons, namely, winter (November-March), spring (April-May), summer (June-August), and fall (September-November). Because of the short spring and fall periods, the spring equations were developed on data from March 16 through June 15; the fall equations used August 16-November 15 as developmental data. Thus, the dependent data sample for those two seasons was enlarged by approximately 50%. The larger sample should contribute to stability in the forecast equations.

The developmental data sample extended from September 1977 through January 1982. Consequently, 690, 360, 360, and 430 days of dependent data were available for the winter, spring, summer, and fall seasons, respectively. As potential model predictors, we used LFM forecasts of height, temperature, thickness, wind, dew point, precipitable water, relative humidity, relative vorticity, temperature advection, vertical velocity, and stability in the low and middle troposphere (Table 2). As mentioned previously, the model fields for these variables were interpolated to the station of interest before the regression was carried out. All LFM predictors were treated as continuous variables and were valid near the verifying time of the predictand. For temperature forecast projections of 42 hours or less, we generally used either unsmoothed model fields or quantities that were filtered by computing an arithmetic average from 5 adjacent points. At the other projections, and for model forecasts that tended to be noisy such as vertical velocity or 1000-mb geostrophic wind, we smoothed the LFM data by a 9- or 25-point arithmetic filter before interpolating to the station. Finally, the first and second harmonics of the day of the year were used as potential predictors to simulate normal climatic values.

For many of the predictands (Groups 1 and 2 in Table 6), we also used the station's surface weather observations in continuous or binary form as potential predictors (Table 3). We've found in other work (Dallavalle et al., 1980) that observations are very important predictors, particularly at forecast projections of 24 hours or less when persistence plays some part in determining the temperature at a station. For any predictand or projection where surface observations are used as potential predictors, we must also derive a set of backup equations that do not use the observations as predictors. Thus, in operations, if a station's report is missing, a forecast can still be produced.

As predictands for the 14 stations in Table 1, we used calendar day (midnight to midnight, local time) max/min temperatures. We then developed equations from 0000 GMT model data to forecast the day 1 max, the day 2 min and max, and the day 3 min, which normally occur approximately 24, 36, 48, and 60 hours, respectively, after 0000 GMT. For 1200 GMT data, equations were developed for the day 2 min and max and the day 3 min and max, occurring approximately 24, 36, 48, and 60 hours, respectively, after 1200 GMT. For these same stations, we also developed equations to predict the temperature at 6-h intervals from 6 to 54 hours after 0000 or 1200 GMT. For the 24 stations shown in Table 4, a similar set of 6-h temperature forecast equations was derived. However, for these sites, calendar day max/min observations were unavailable in our data archive and so no max/min equations were produced. Fig. 1 shows the Alaskan MOS stations for which guidance is transmitted to NWS forecasters. Figs. 2 and 3 give time lines demonstrating the relationship of the calendar day max/min to the 6-h temperatures for the 0000 and 1200 GMT forecast cycles, respectively.

4. EXPERIMENTS IN DEVELOPING LFM-BASED TEMPERATURE FORECAST EQUATIONS

Before developing a new set of operational forecast equations, we compared the accuracy of experimental LFM-based forecast equations with the skill of the then operational PE-derived equations. As a first step, max/min forecast equations were developed from the LFM model for the 14 stations listed in Table 1. Winter (November-March) season equations were produced for the 0000 GMT forecast cycle. Like in the operational PE-derived equations, a maximum of 10 predictors was allowed. Equations were available to predict the day 1 max, the day 2 min and max, and the day 3 min. Developmental data consisted of the period from November 1, 1977 through March 31, 1980. We used the predictors discussed in Tables 2 and 3 to develop equations both with (primary) and without (backup) observations for the day 1 max and the day 2 min. The model predictors in Table 2 were used to derive the equations for the day 2 max and day 3 min.

In the PE-derived forecast system, winter equations were valid for the December-February period only. To make our test as comparable and as simple as possible, we produced forecasts from both the PE- and LFM-derived equations on independent data from December 1, 1980 through February 28, 1981. Approximately 90 days of model output were available during this time. Thus, for both the PE- and LFM-derived systems, we used winter season equations to make the independent forecasts. For the LFM-based system, the equations were, of course, applied to the LFM model. The PE-based equations were, however, applied to spectral model output since this model became the basis for all Alaskan forecast equations in August 1980.

For comparison, we made several other types of control forecasts. In one case, persistence, namely,the previous day's max or min observation, was used to make forecasts of the following day's max or min, as appropriate. We also made climatic forecasts by deriving regression equations based solely on the first and second harmonics of the day of the year. Finally, we generated persistence-climate forecasts from regression equations that depended only on the previous max or min observation and the first and second harmonics of the day of the year.

Our results are shown in Table 5. Note that the number of cases for the primary day 1 max and day 2 min forecasts were fewer than for the backup equations. Because of missing observations, we were unable to derive primary LFM-based equations for Annette, St. Paul Island, or Barter Island. Clearly, the LFM-based guidance is superior to the forecasts produced by applying PE equations to spectral model output. When surface observations were not used in the equations, the LFM-based forecasts were 1.9°F mean absolute error more accurate than the spectral-based guidance for all four forecast projections combined. The latter set of forecasts had a distinct cold bias (negative algebraic error). Moreover, for the day 2 min and max and the day 3 min, over 40% of the spectral-based forecasts were in error by more than 7°F The forecasts based on climate, persistence, or persistence-climate were generally much less accurate than the LFM-based MOS max/min temperatures.

Fig. 4 shows the mean absolute errors by projection for the LFM- and spectral-based guidance for the December 1980-February 1981 test period. In this case, both the backup and primary equations were used on a matched sample for 11 stations. The superiority of the LFM guidance is evident. Note, the difference in accuracy of the primary and backup LFM guidance for the day 2 min is only 0.1°F. When plotted, the mean absolute errors for the LFM forecasts tend to exhibit a saw-toothed pattern, that is, the errors for the min forecasts are higher than the max for the same or adjacent days. Consequently, the error for the day 2 min is greater than that for the day 2 max which normally occurs later in the day. We see this pattern repeatedly in verification scores for max/min guidance in the conterminous United States (Carter et al., 1982). Generally, we have found that the min is more difficult to forecast than the max in the winter because small-scale effects like stratus clouds or drainage winds tend to control night-time cooling while the max is apt to be influenced by synoptic-scale events that are better predicted by the numerical models.

Fig. 5 is an example of the geographical distribution of the mean absolute error for the primary day 2 min forecast. At nine of the 11 stations, the LFM-based test forecasts were more accurate than the operational guidance. Note, however, the large errors in the LFM predictions at McGrath and King Salmon. Note, too, the apparent superiority of the operational guidance at Nome and Kotzebue in northwest Alaska. This could be related to the closeness of Alaska to the boundary of the LFM grid, although chance may be an equally valid explanation. For the day 2 max and the day 3 min (not shown), the LFM guidance was superior at virtually all stations.

We also experimented with several different potential predictor lists. In the past (Dallavalle and Hammons, 1977), we found that the accuracy of the temperature forecast equations was not sensitive to minor changes in the predictor list. However, in our Alaskan development with so few stations involved, we though that we might be able to detect some improvement in the accuracy of the guidance if we altered predictor smoothings. We have not shown the results of any of our tests here; basically, we found again that changing the smoothing of predictors did not significantly change the forecast accuracy.

As mentioned earlier, we want consistency in the temperature guidance. In other words, the max forecast should not be less than the min forecast for the same day. Additionally, the temperature forecasts at specific hours should not be greater than the max forecast for that calendar day nor less than the min forecast for the same day. As discussed in Dallavalle et al. (1980), when we developed LFM temperature guidance for the conterminous United States, we showed that simultaneously deriving 3-h temperature and max/min forecast equations considerably enhanced consistency in the forecasts. Thus, we decided to derive simultaneously the new LFM-based max/min and 6-h temperature equations for the 14 Alaskan stations shown in Table 1.

To determine how to combine the various temperature predictands, we examined temperature observations at 3-h intervals from November 1972 through August 1981, stratified according to season. Diurnal temperature variations were considered for all 14 of the Alaskan stations. Figs. 6 and 7 show sample average temperature curves at Juneau and McGrath, respectively. We found that the average time of occurrence of the max or min varied by station and season of the year; generally, however, the max occurred around 0000 or 0300 GMT and the min was observed between 1200 and 1800 GMT. On this basis, we stratified the predictands according to the list given in Table 6. With this division, we think that inconsistencies in the Alaskan temperature guidance will be minimized. Also, equations for the min and max for the same day were derived simultaneously with each other.

We tested to see if the simultaneous derivation of the equations caused a deterioration in the quality of the max/min guidance. For the 0000 GMT cycle, we derived a set of day 2 min/max equations using the simultaneous approach. Observations were not used as predictors and 12 terms were allowed in the equations to account for the additional predictands. Using these equations and the day 2 min and max LFM-based equations developed separately, we made forecasts for the December 1980-February 1981 season. Mean absolute errors by station are given in Figs. 8 and 9. Overall, in terms of the mean absolute error, there was no significant change in skill when the simultaneously derived equations were used.

Results from doing an analogous test on 1200 GMT data are give in Table 7. Equations were derived simultaneously and separately for the day 2 min, the day 2 max, the day 3 min, and the day 3 max. Surface observations were not used as predictors and 12 terms were allowed in the equations. Again, while there were small differences in skill between the two methods at individual stations, these differences may have been due to the small sample size. Overall, the simultaneous derivation yielded results that were at least as accurate as the separate derivation. Interestingly, we found two cases in this test when the day 2 max forecast produced by the separately-derived equations was less than the day 2 min forecast. The simultaneously-derived equations did not have this problem.

5. DEVELOPMENT OF OPERATIONAL FORECAST EQUATIONS

When our various experiments were completed, we developed operational LFM-based forecast equations, using the simultaneous approach discussed earlier. The grouping of the predictands was identical to that presented in Table 6. For each station listed in Table 1, equations to predict the calendar day max/min and the surface temperature at 6-h intervals from 6 to 54 hours after initial model time were developed for both cycles, each predictand, and each season. Lacking calendar day max/min observations for the stations in Table 4, we only derived 6-h temperature equations for these sites. The stratification of the temperature predictands was, however, identical to that shown in Table 6. Because some of the stations in Tables 1 and 4 were closed at certain hours during the period of the developmental sample, we could not derive equations for every station and every projection. Note, too, in Table 6 that two temperature equation sets were developed for the 30-h projection from 0000 GMT and for the 18- and 42-h projection from 1200 GMT. This was done to produce smoother temperature forecast curves at these transitional hours. In operations, the temperature forecasts from the two sets of equations are averaged to give the appropriate guidance.

The specific LFM and climatic predictors used to develop the 0000 GMT Group 2 and Group 3 (in Table 6) forecast equations are given in Tables 8 and 9, respectively. The predictors for the other projections are analogous except the predictor projections vary slightly for the different predictands. For the Group 1 and Group 2 equations at both cycles, we also used the station observations given in Table 3 as additional potential predictors. Because station observations are not always available in an operational environment, equations that exclusively use model fields and climatic terms were developed for the same predictands.

During the regression procedure, equation development was stopped when 12 terms were selected or when no predictor added at least 0.25% to the total reduction of variance. For the Group 3 equations at 0000 GMT, only 10 terms were allowed. Except for this set, the regression procedure selected 12 terms for most of the forecast equations. As discussed earlier, the developmental data were divided into winter, spring, summer, and fall seasons. Although the spring and fall developmental season extended from March 16 through June 15 and from August 16 to November 15, respectively, the spring and the fall equations are used operationally only for the April-May and September-October periods.

The standard errors of estimate (root mean square error) for the developmental sample are shown for the 0000 and 1200 GMT winter equations in Figs. 10 and 11, respectively. The primary (with observations) 6-h temperature equations are more accurate than the backup (model and climate terms only) equations, particularly at the 6- through 18-h projections. Beyond 18 hours, the differences in standard error decrease. By 36 hours, the standard errors for the primary and backup equations are about the same. For the max/min forecast equations, the primary equations produce smaller standard errors of estimate for the day 1 max and day 2 min from 0000 GMT. For the other projections, differences between the primary and backup equations are small. The errors for both the 6-h temperature and max/min forecast equations tend to increase with increasing projection, although not monotonically. Afternoon temperatures are somewhat more predictable than nighttime temperatures during the Alaskan winter; it is also easier to forecast the max rather than the min for a given day. The standard errors for the other 3 seasons are analogous, although the values are not as large and the primary equations are only slightly better than the backup equations at projections beyond 24 hours and for any of the max/min forecasts. The trend of the max/min standard errors during the fall closely resembles the pattern seen in the winter season. During the spring, the errors increase monotonically with time. For the summer, the standard error pattern is the reverse of that seen in the winter. In other words, the max is more difficult to predict than the min, likely because of mesoscale convective activity.

In our developmental work, we found that the most important predictors at all projections were the initially analyzed surface temperature; the cosine of the day of the year and of twice the day of the year; and model forecasts of the 850-1000 mb thickness, the 850-mb temperature, the dew points at 850 and 1000 mb, and the mean relative humidity. When surface observations were included as predictors, the latest observed temperature and dew point were important fields.

6. FORECAST PREPARATION AND DISSEMINATION

The Alaskan temperature forecasts are prepared each day around 0330 and 1600 GMT as part of a more complete Alaskan MOS guidance package (National Weather Service, 1983). The forecasts are disseminated in the FMAK1 bulletin (Fig. 12) for the 29 stations shown in Fig. 1. Guidance for all stations, including military bases, is sent to the U.S. Air Force's Global Weather Center in a special message. The FMAK1 bulletin for the 0000 (1200) GMT forecast cycle gives the day 1 max (day 2 min), day 2 min (day 2 max), day 2 max (day 3 min), and day 3 min (day 3 max) temperatures in consecutive order. These calendar day forecasts are identified by the MX/MN (MN/MX) symbols. Temperature forecasts, denoted by TEMP, are also provided for projections of 12, 18, 24, 30, 36, 42, 48, and 54 hours. For those stations and projections where forecasts can not be made, a value of 999 appears in the message.

When using the MOS guidance, the forecaster should remember that the max/min temperature forecasts are valid for the calendar day and do not necessarily coincide with the 6-h temperatures. For example, if the maximum occurs near midnight local time, the 6-h temperature forecast for a specific time during the late afternoon will likely not be as high as the max value. Moreover, no consistency checks are made operationally for the temperature guidance. It is possible that the calendar day max (min) forecast will occasionally be less (more) than a particular 6-h temperature for the same day.

As with all of the MOS products, the forecaster must use the temperature guidance judiciously. The MOS forecasts depend on the accuracy of the LFM model. If the forecaster has reason to believe that the LFM model has gone awry or is showing a non-systematic error, he or she should modify the guidance accordingly. The forecaster should develop his/her own station climatology and be alert to those synoptic situations that the MOS guidance does not predict well. Unusual or rare meteorological events, even cases as innocuous as drought or abnormally warm winters, often are times when the MOS forecasts are consistently in error. In the short range, the forecaster has the advantage of using recent observations, radar reports, satellite photographs, and reports from surrounding stations that do not go into the MOS guidance. At the later projections, the forecaster should remember that a technique like MOS tends to revert to forecasts of normal values.

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Table 1. Alaskan stations for which maximum/minimum and 6-h temperature forecast equations were derived. The asterisk (*) indicates stations where temperature guidance is unavailable for projections coinciding with 0600 GMT.

Anchorage (ANC)	Juneau (JNU)
Annette (ANN)*	King Salmon (AKN)
Barrow (BRW)	Kotzebue (OTZ)
Barter Island (BTI)*	McGrath (MCG)
Bethel (BET)	Nome (OME)
Cold Bay (CDB)	St. Paul Island (SNP)*
Fairbanks (FAI)	Yakutat (YAK)

Table 2. LFM model predictors used in the derivation of the Alaskan maximum/minimum and 6-h temperature forecast equations.

Height - 850 mb, 500 mb
Temperature - surface, 1000 mb, 850 mb, 700 mb
Temperature advection - 850 mb
Thickness - 500-1000 mb, 850-1000 mb, 700-850 mb
Dew point - 1000 mb, 850 mb, 700 mb
Dew point depression - 1000 mb, 850 mb, 700 mb
Geostrophic u, v wind components - 1000 mb
Geostrophic wind speed - 1000 mb
U, v wind components - 850 mb, 700 mb
Wind speed - 850 mb
Relative vorticity - 850 mb, 500 mb
Vertical velocity - 700 mb
K index
Mean relative humidity (surface to $\sim$ 500 mb)
Precipitable water

Table 3. Reporting time of surface observations used as potential predictors in deriving LFM-based temperature forecast equations for Alaska. Except where indicated, the predictors are continuous. The previous day's max and min are used as predictors only for the 14 stations in Table 1.

Observation	Forecast Cycle	
	0000 GMT	1200 GMT
Sfc temperature	0300	1500
Sfc temperature	0000	1200
Sfc dew point	0300	1500
Opaque sky cover (binary)	0300	1500
Sfc u wind	0300	1500
Sfc v wind	0300	1500
Sfc wind speed	0300	1500
Ceiling height (binary)	0300	1500
Previous max	-	1200
Previous min	0000	-

Table 4. Stations in Alaska for which only 6-h temperature forecast equations were developed. Locations denoted by AFB are U.S. Air Force bases; MOS temperature forecasts for these sites are not transmitted on the FMAK1 bulletin. Forecasts for projections coinciding with 0600 and 1200 GMT are unavailable for Petersburg and Skagway. Guidance for projections corresponding to 1200 GMT is unavailable for Tanana.

Bettles (BTT)	Indian Mountain AFB (PAIM)
Big Delta (BIG)	Kenai (ENA)
Cape Lisburne AFB (PALU)	Kodiak (ADQ)
Cape Newenham AFB (PAEH)	Northway (ORT)
Cape Romanzoff AFB (PACZ)	Petersburg (PSG)
Cordova (CDV)	Sitka (SIT)
Dillingham (DLG)	Skagway (SGY)
Eielson AFB (PAEI)	Sparrevohn AFB (PASV)
Elmendorf AFB (PAED)	Talkeetna (TKA)
Galena (PAGA)	Tanana (TAL)
Gulkana (GKN)	Tatalina AFB (PATL)
Homer (HOM)	Tin City AFB (PATC)

Table 5. Verification of 0000 GMT max/min temperature forecasts made for 14 stations in Alaska for the period of December 1, 1980 through February 28, 1981. Forecasts were dependent on LFM model output (LFM), spectral model output (SM), persistence (P), climate (C), or persistence and climate (P-C) combined. The LFM-based and spectral-based guidance were derived from LFM and PE model output, respectively. The PE equations were operational during the December 1980-February 1981 period. All errors are given in °F.

Forecast Type	Forecast Method	Mean Algebraic Error	Mean Absolute Error	Root Mean Square Error	No. of Cases (%) of Absolute Error > 7	Total No. of Cases
Day 1 Max (Primary)	LFM	0.6	4.5	6.1	171 (17.5)	979
	SM	-2.4	4.8	6.3	200 (20.4)	
Day 1 Max (Backup)	LFM	0.4	4.6	6.2	237 (19.0)	1246
	SM	-3.1	6.6	8.4	416 (33.4)	
	P	-0.1	5.3	7.7	293 (23.5)	
	C	-1.4	12.0	15.0	772 (62.0)	
	P-C	-0.2	5.3	7.5	312 (25.0)	
Day 2 Min (Primary)	LFM	-0.3	6.3	8.2	307 (31.4)	979
	SM	-4.5	7.3	9.4	397 (40.6)	
Day 2 Min (Backup)	LFM	0.0	6.0	7.8	376 (30.2)	1246
	SM	-5.6	8.0	10.2	554 (44.5)	
	P	-0.2	9.3	12.7	591 (47.4)	
	C	-2.1	13.4	15.9	891 (71.5)	
	P-C	-0.9	9.2	11.7	623 (50.0)	
Day 2 Max	LFM	0.5	5.7	7.7	365 (29.3)	1246
	SM	-5.1	8.0	10.2	573 (46.0)	
	P	-0.2	8.1	11.3	500 (40.1)	
	C	-1.6	12.0	14.9	765 (61.4)	
	P-C	-0.7	8.0	10.6	505 (40.5)	
Day 3 Min	LFM	0.0	7.3	9.5	493 (39.6)	1246
	SM	-5.4	8.7	11.2	591 (47.4)	
	P	-0.2	10.7	14.5	649 (52.1)	
	C	-2.2	13.4	15.9	890 (71.4)	
	P-C	-1.4	10.7	13.1	742 (59.6)	

Table 6. Combination of predictands used for the simultaneous derivation of the Alaskan max/min and 6-h temperature forecast equations.

Cycle	Group No.	Max/Min Projections	6-H Temperature Projections
0000 GMT	1	Day 1 Max	6,12,18,24,30
	2	Day 2 Min Day 2 Max	30,36,42,48,54
	3	Day 3 Min	-
1200 GMT	1	-	6,12,18
	2	Day 2 Min Day 2 Max	18,24,30,36,42
	3	Day 3 Min Day 3 Max	42,48,54

Table 7. Verifications for 1200 GMT test forecasts made from LFM-based max/min equations for the December 1980-February 1981 period.

Forecast	Derivation Method	Mean Algebraic Error	Mean Absolute Error	No. of Cases
Day 2 Min	Separate	-0.3	5.7	1068
	Simultaneous	-0.4	5.7	
Day 2 Max	Separate	0.3	5.4	1068
	Simultaneous	0.1	5.5	
Day 3 Min	Separate	-0.4	7.1	979
	Simultaneous	-0.4	7.1	
Day 3 Max	Separate	0.3	6.8	979
	Simultaneous	0.1	6.7	

Table 8. Predictors used for the derivation of the 0000 GMT Group 2 forecast equations. All model fields marked by a single or double asterisk were filtered by a 5- or 9-point arithmetic average, respectively.

LFM Model Field	Projection
Surface temperature	0
1000-mb temperature	36*,48**
850-mb temperature	30*,36*,42*,48**
700-mb temperature	36*,48**
1000-mb geostrophic u wind	30*,36*,42*,48**
1000-mb geostrophic v wind	30*,36*,42*,48**
1000-mb geostrophic wind speed	30*,36*,42*,48**
850-mb u wind	30*,36*,42*,48**
850-mb v wind	30*,36*,42*,48**
850-mb wind speed	30*,36*,42*,48**
700-mb u wind	36*,48**
700-mb v wind	36*,48**
850-mb height	36*,48**
500-mb height	36*,48**
500-1000 mb thickness	30,36,42,48*
850-1000 mb thickness	30,36,42,48*
700-850 mb thickness	30,36,42,48*
1000-mb dew point	36*,48**
850-mb dew point	36*,48**
700-mb dew point	36*,48**
1000-mb dew point depression	36*,48**
850-mb dew point depression	36*,48**
700-mb dew point depression	36*,48**
Precipitable water	30*,36*,42*,48**
Mean relative humidity	30*,36*,42*,48**
850-mb relative vorticity	36*,48**
500-mb relative vorticity	36*,48**
850-mb temperature advection	30*,36*,42**,48**
700-mb vertical velocity	36**,48**
K index	36*,48**

Climatic Field

Sine $\frac{(2 \times \pi)}{365} \times$ day of year

Cosine $\frac{(2 \times \pi)}{365} \times$ day of year

Sine $\frac{(4 \times \pi)}{365} \times$ day of year

Cosine $\frac{(4 \times \pi)}{365} \times$ day of year

Table 9. Predictors used for the derivation of the 0000 GMT Group 3 forecast equations. All model fields marked by a double or triple asterisk were filtered by a 9- or 25-point arithmetic average, respectively.

LFM Model Field	Projection
Surface temperature	0
1000-mb temperature	48**
850-mb temperature	48**
700-mb temperature	48**
1000-mb geostrophic u wind	48***
1000-mb geostrophic v wind	48***
1000-mb geostrophic wind speed	48***
850-mb u wind	48**
850-mb v wind	48**
850-mb wind speed	48**
700-mb u wind	48**
700-mb v wind	48**
850-mb height	48**
500-mb height	48**
500-1000 mb thickness	48**
850-1000 mb thickness	48**
700-850 mb thickness	48**
1000-mb dew point	48**
850-mb dew point	48**
700-mb dew point	48**
1000-mb dew point depression	48**
850-mb dew point depression	48**
700-mb dew point depression	48**
Precipitable water	48**
Mean relative humidity	48**
850-mb relative vorticity	48***
500-mb relative vorticity	48***
850-mb temperature advection	48***
700-mb vertical velocity	48***
K index	48***

Climatic Field

Sine $\frac{(2 \times \pi)}{365} \times$ day of year

Cosine $\frac{(2 \times \pi)}{365} \times$ day of year

Sine $\frac{(4 \times \pi)}{365} \times$ day of year

Cosine $\frac{(4 \times \pi)}{365} \times$ day of year

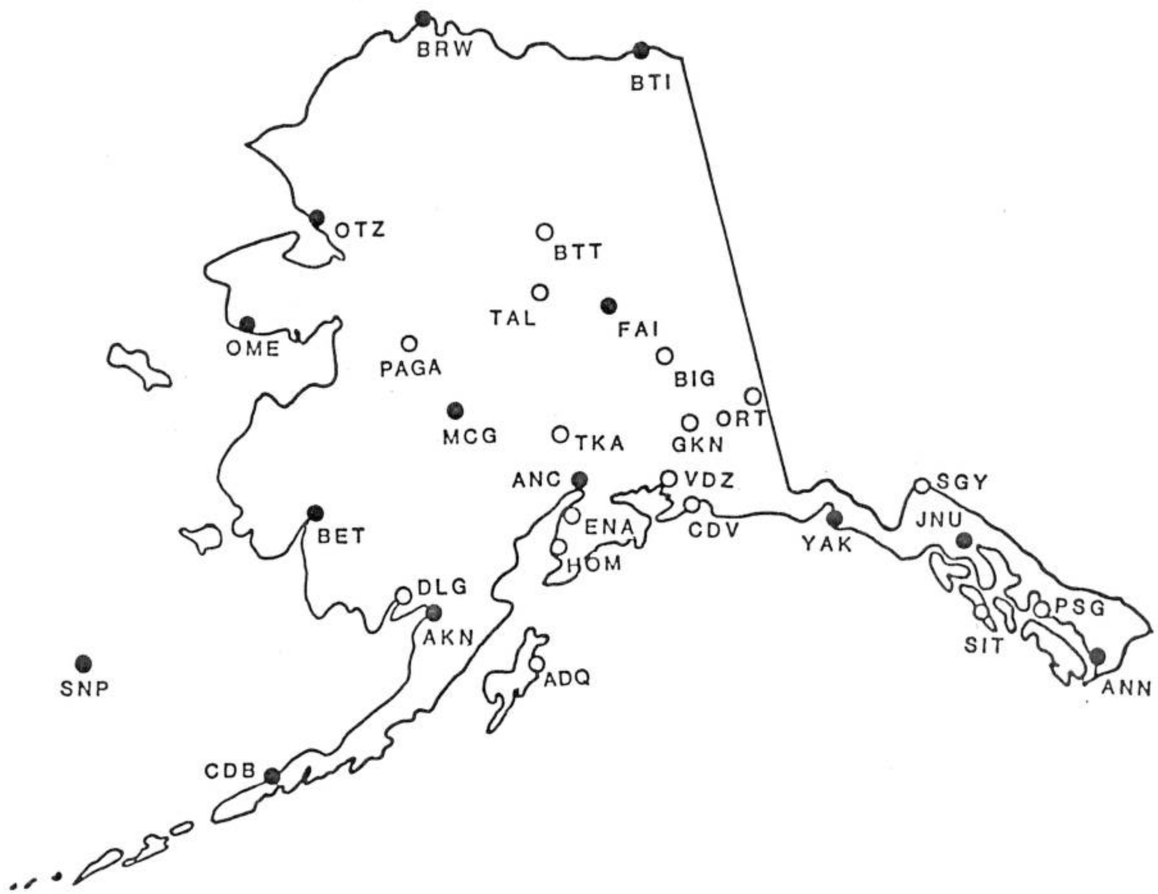

Figure 1. Location of stations in Alaska for which temperature forecasts are produced and disseminated on the FMAK1 bulletin. The shaded circles denote stations that have both max/min and 6-h temperature forecasts.

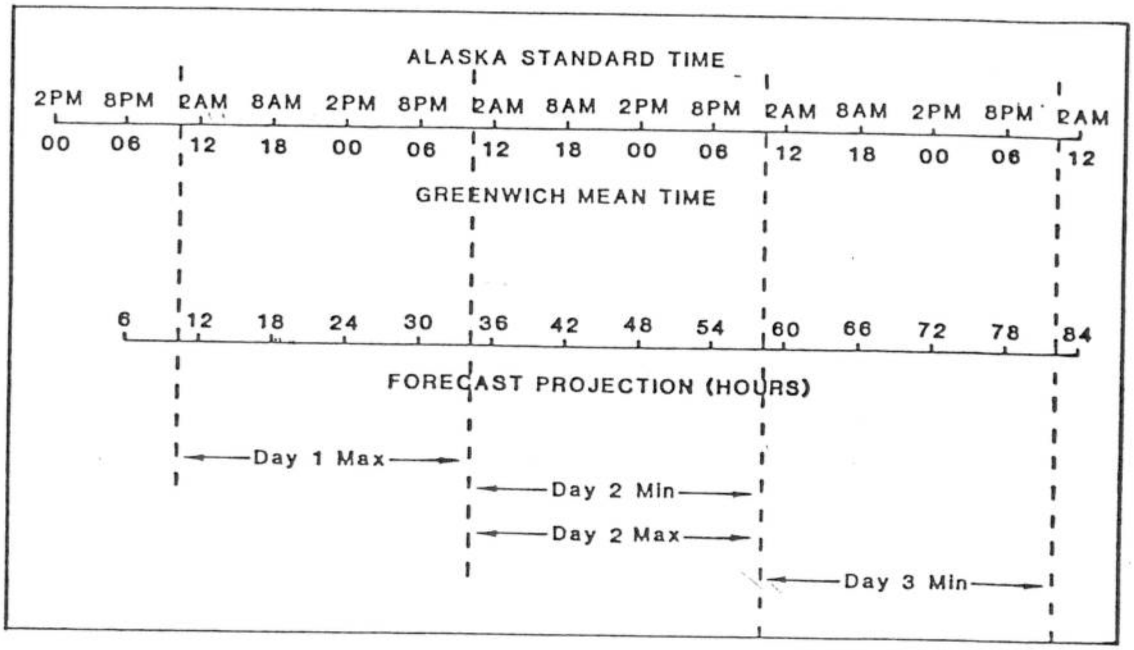

Figure 2. Projection and corresponding local time for the temperature forecasts produced during the 0000 GMT forecast cycle.

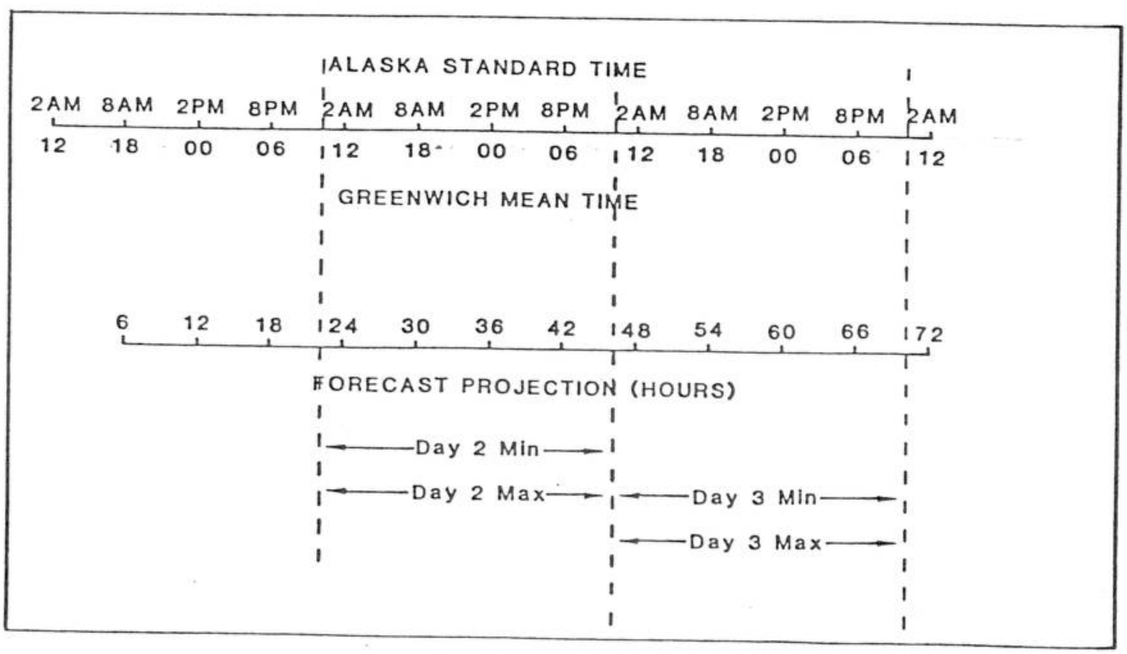

Figure 3. Same as Fig. 2 except for the 1200 GMT cycle.

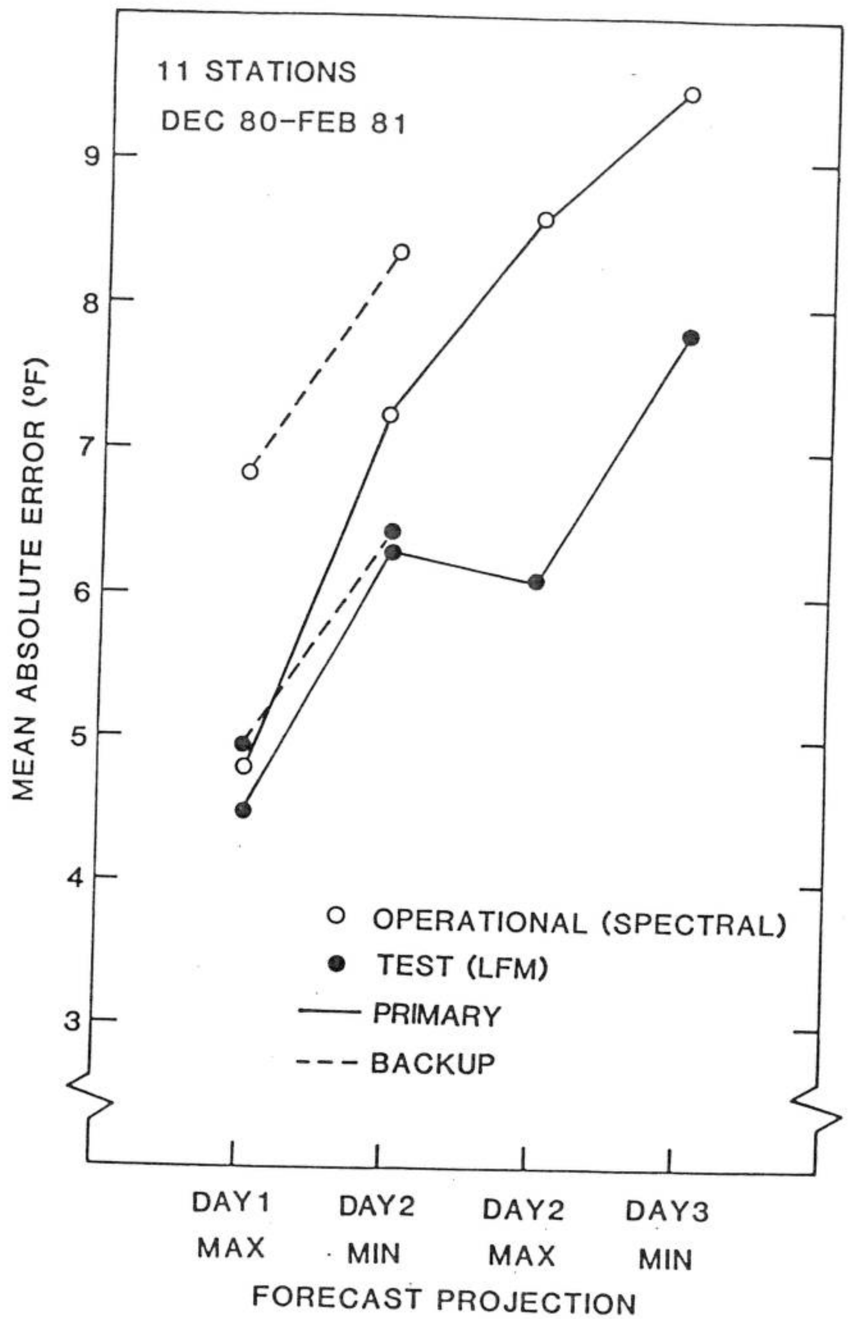

Figure 4. Mean absolute error (°F) by projection for the December 1980-February 1981 period. For the first two periods, forecasts were generated by equations (primary) that included observations as predictors and by equations (backup) that used only model and climatic terms.

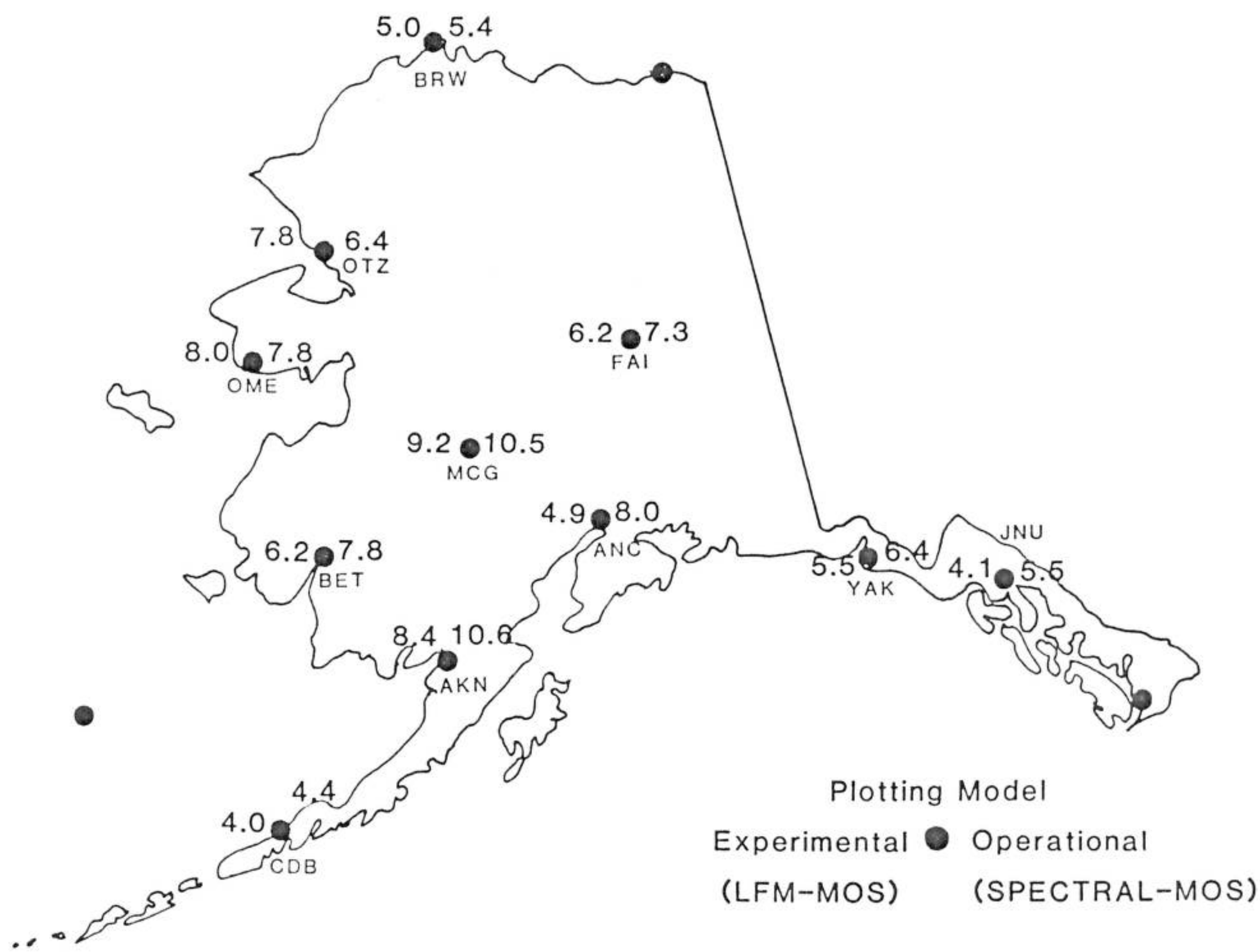

Figure 5. Mean absolute error (^{o}F) by station for the day 2 minimum temperature forecast from 0000 GMT. These forecasts were generated by the primary (with observations) experimental and operational equations for the December 1980 through February 1981 period.

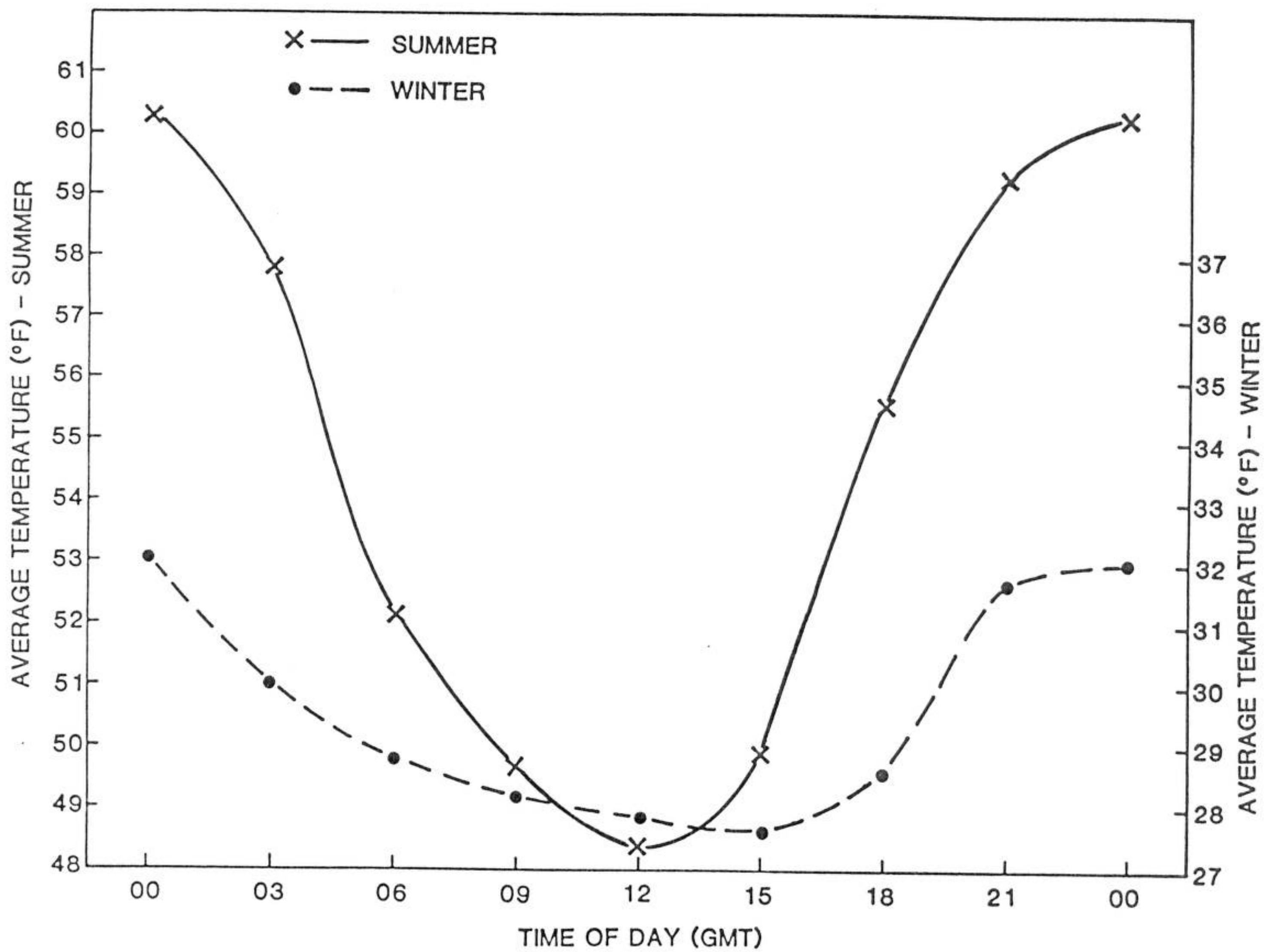

Figure 6. Average temperature (^{o}F) at 3-h intervals for Juneau, Alaska during winter (November-March) and summer (June-August). The mean values were based on data from November 1972-August 1981.

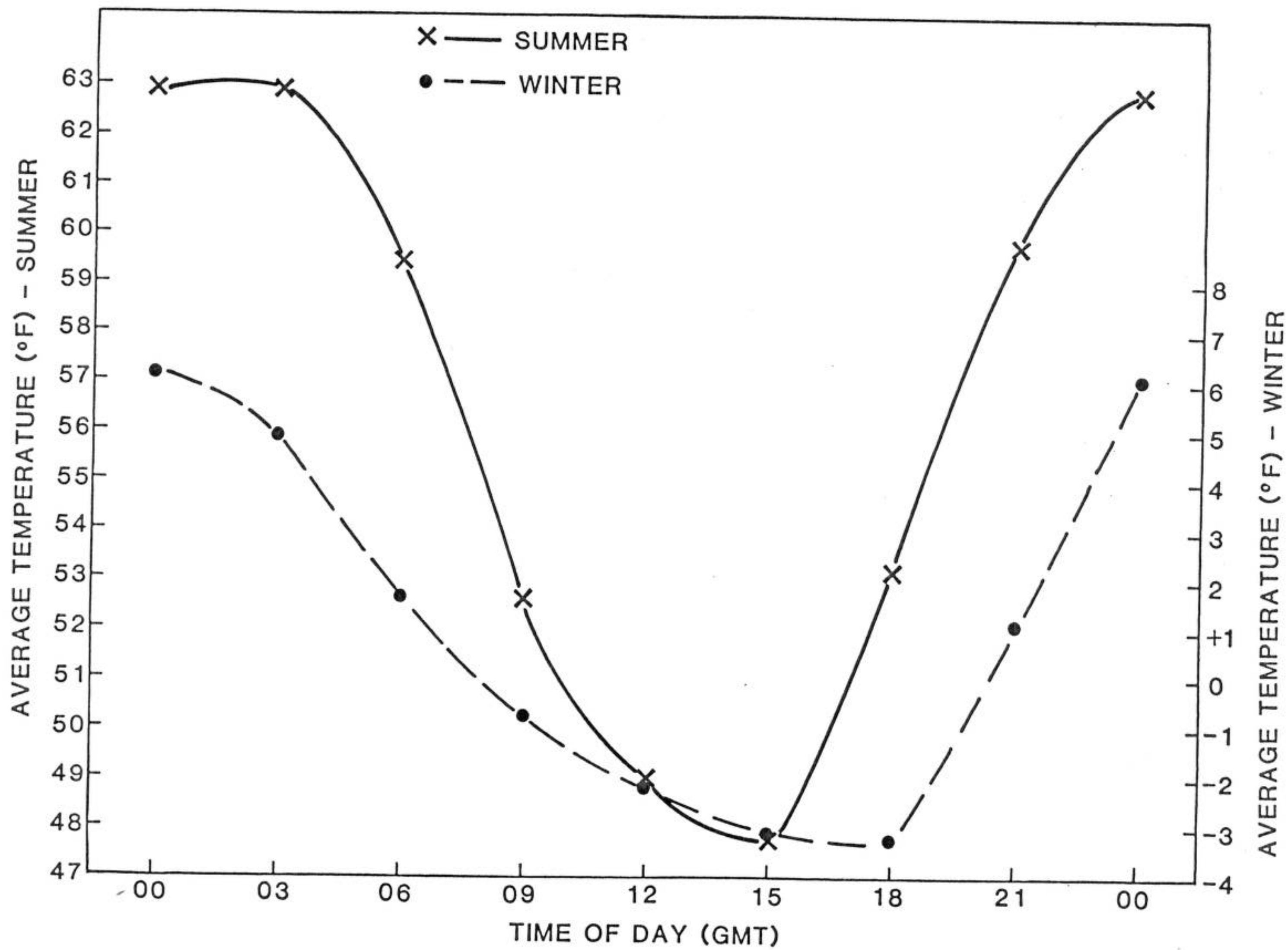

Figure 7. Same as Fig. 6 except for McGrath, Alaska.

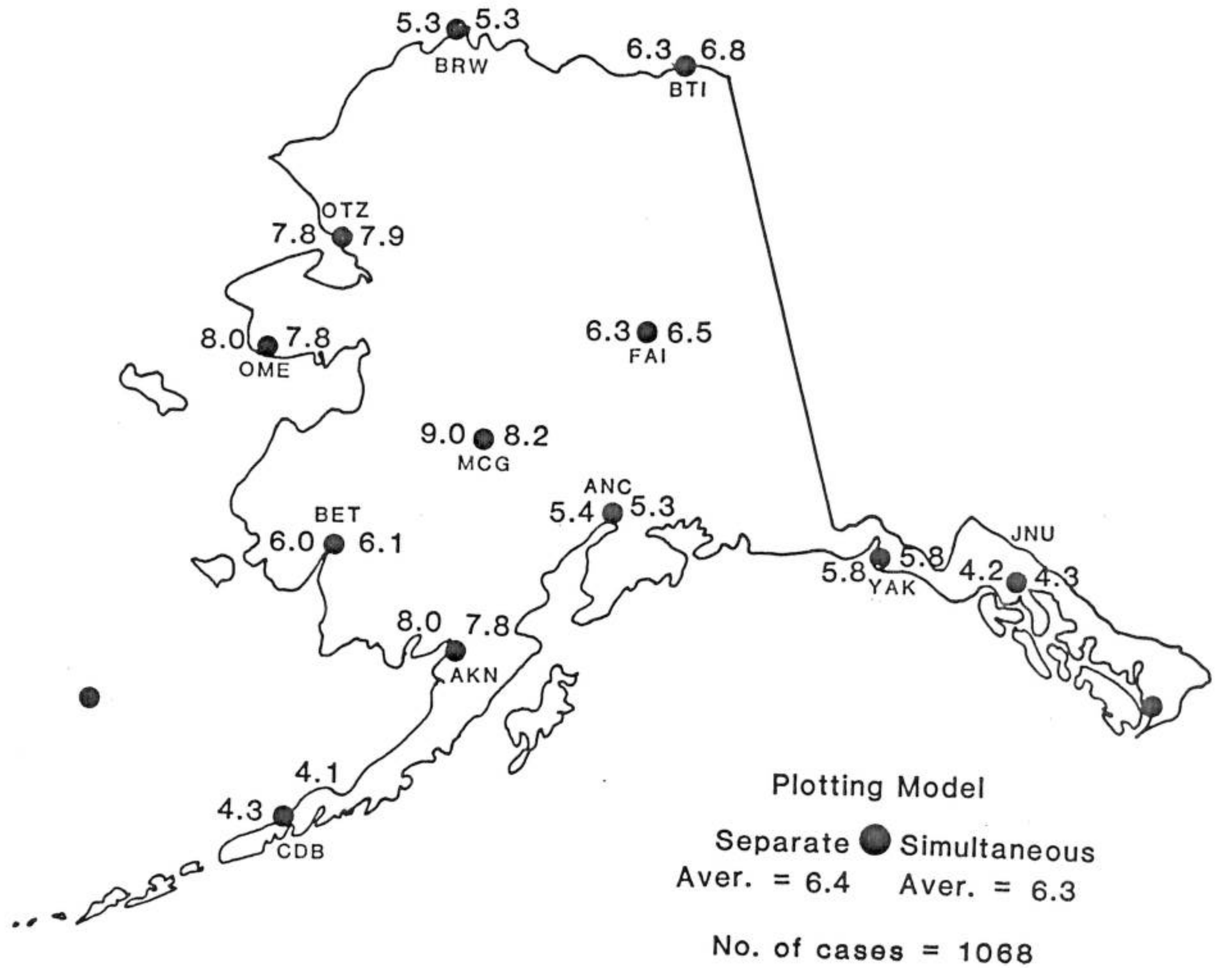

Figure 8. Mean absolute error (^{o}F) by station for the day 2 minimum temperature forecast from 0000 GMT. These forecasts were generated by equations that used only model fields and climatic terms as predictors. The guidance was produced for the December 1980 to February 1981 period. Errors to the left of the station circle are for equations derived separately from the 6-h temperature equations; errors to the right are for equations derived simultaneously with the 6-h equations.

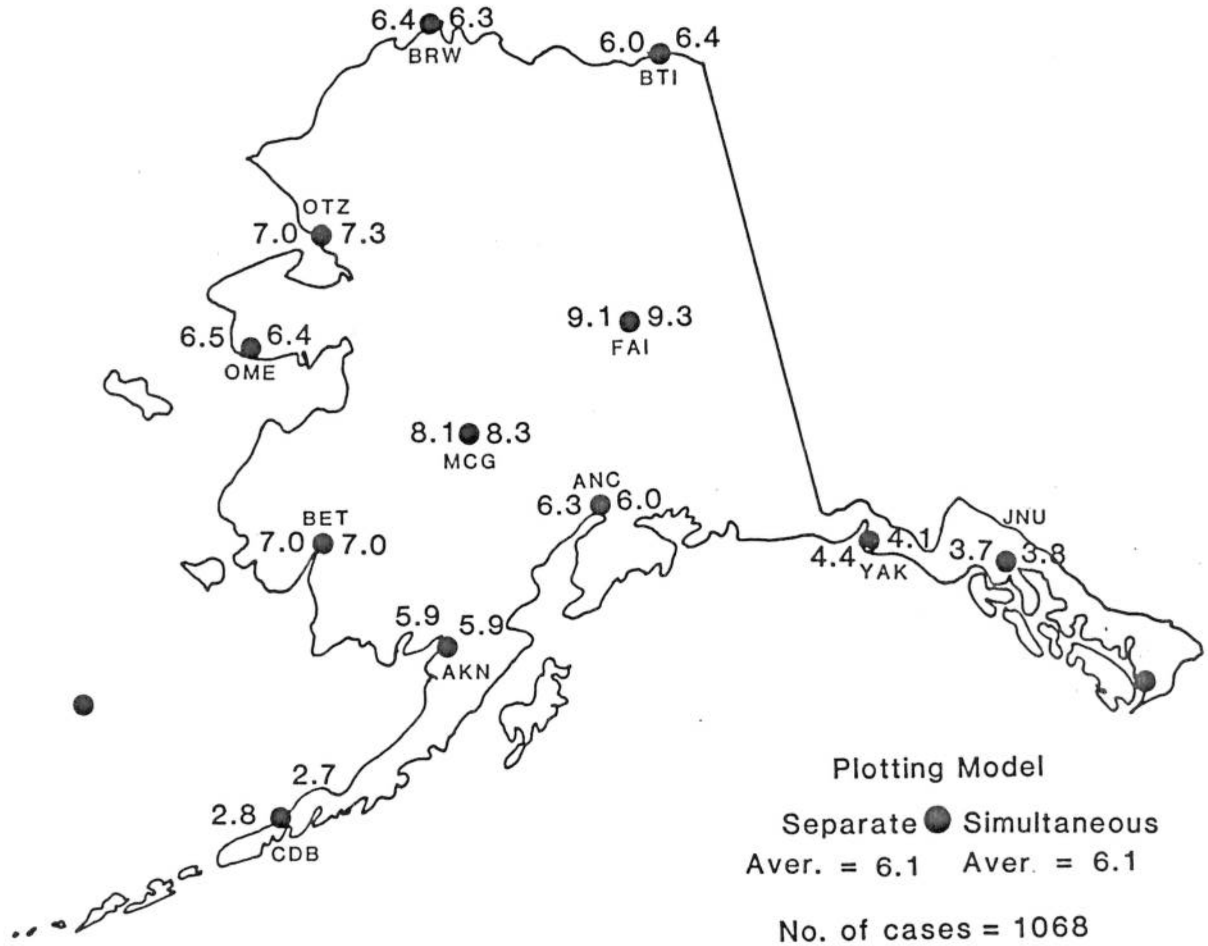

Figure 9. Same as Fig. 8 except for the day 2 maximum temperature from 0000 GMT.

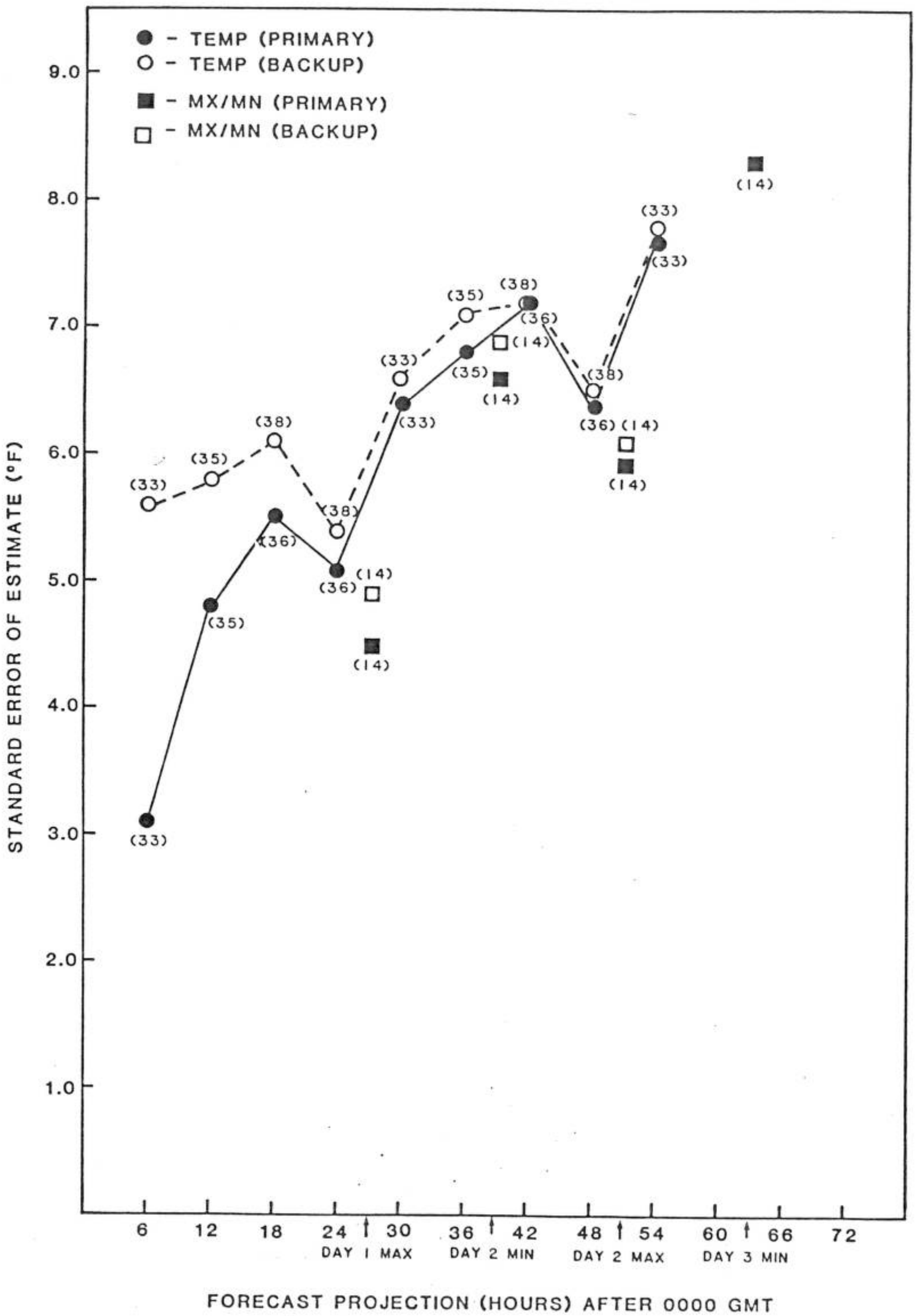

Figure 10. Standard error of estimate (^{o}F) for the 0000 GMT winter maximum/minimum and 6-h temperature forecast equations. The number in parentheses denotes the number of stations with forecast equations.

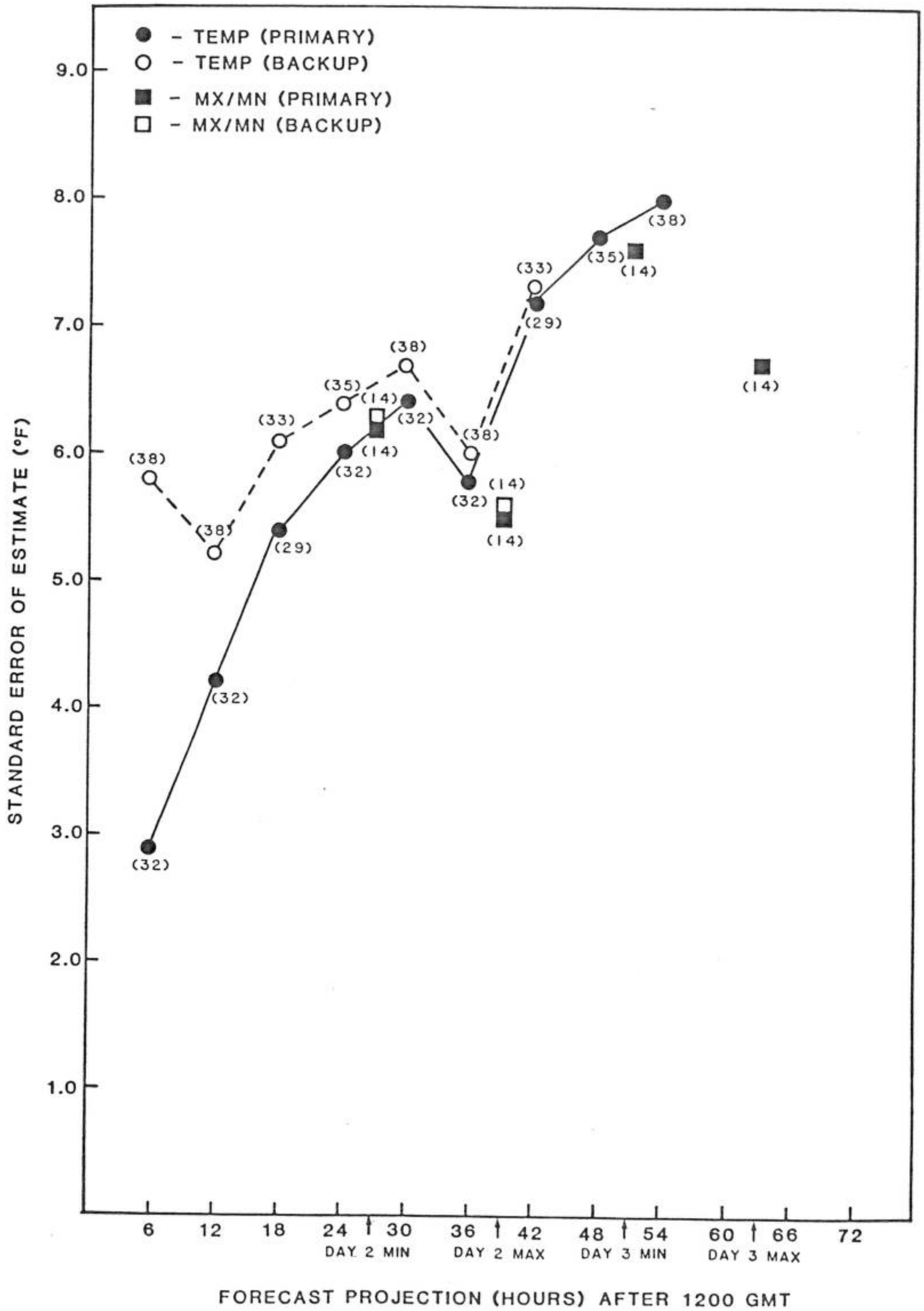

Figure 11. Same as Fig. 10 except for the 1200 GMT equations.

HDNG ALASKAN LFM-BASED MOS GUIDANCE 10/22/82 0000 GMT

DATE/GMT		22/12	22/18	23/00	23/06	23/12	23/18	24/00	24/06
ANC	POP06	10	30	40	10	10	10	5	10
	POP12		30		50		10		20
	POF	41	12	6	4	50	71	72	85
	MX/MN			40		24		32	22
	TEMP	30	35	38	37	29	27	31	24
	WIND	2404	2610	1807	1411	1907	1109	0206	3508
	CLDS	1008/4	0217/4	1217/4	1117/4	1360/3	1270/3	1181/3	2431/2

Figure 12. Sample FMAK1 message for Anchorage, Alaska from October 22, 1982 (0000 GMT).