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OBJECTIVE FORECASTS OF SOME RECORD-BREAKING MINIMUM TEMPERATURES DURING DECEMBER 1983

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1. INTRODUCTION

During December 1983, Arctic air masses repeatedly moved southward across the conterminous United States from Alaska and the Northwest Territories of Canada. While affecting the central and eastern United States, these cold air outbreaks were responsible for shattering numerous minimum temperature records. We investigated how the Model Output Statistics (MOS) temperature guidance handled one such record-breaking Arctic anticyclone during December 24 through December 26, 1983. This particular period was selected because the severe cold caused extensive damage to the citrus and vegetable crops in Texas and Florida. The results of this study indicate that the MOS minimum temperature forecasts provided useful information to the forecasters at cities where new temperature records were established.

2. APPROACH

Figs. 1-3 show the minimum (min) temperatures observed over a 12-h period ending at 1200 GMT on December 24, December 25, and December 26, 1983, respectively. Also included on these charts is a list of stations reporting min temperatures that equaled or broke previous record values. These stations are identified by World Meteorological Organization (WMO) station numbers. Adjacent to the identifier is the reported observed min and the type of record that was tied or broken. These records are encoded as the acronyms LOEDA, LOEFM, LOXDA, and LOXFM which indicate, respectively, that the lowest temperature for the day was equaled, the lowest temperature for the month was equaled, the lowest temperature for the day was exceeded, and the lowest temperature for the month was exceeded. We looked at the MOS min guidance only for those record-reporting stations on these charts. By doing this, we are not implying that no other temperature records were broken; we simply selected data that were easily accessible. Where possible, we verified the reported temperatures by consulting our archive of observed hourly data.

The MOS min temperature forecasts (Dallavalle et al., 1980; National Weather Service, 1980) provide LFM-based guidance for calendar day values (midnight to midnight, local time) at a station. In particular, from the 0000 GMT forecast cycle, we produce forecasts of tomorrow's and the day after tomorrow's min temperatures that are often valid approximately 36 and 60 hours, respectively, after 0000 GMT. Similarly, at the 1200 GMT cycle, min temperature guidance is available for tomorrow's and the day after tomorrow's min. Under normal circumstances, these values verify approximately 24 and 48 hours, respectively, after 1200 GMT. The MOS temperature guidance is provided to the forecaster in both graphical (National Weather Service, 1980) and alphanumeric (National Weather Service, 1983a; National Weather Service, 1983b) form. For this study, we examined only the first min temperature forecast from 0000 GMT and the two min temperature forecasts from 1200 GMT data. In our opinion, the forecast (approximately 60 hours) of the day after tomorrow's min temperature generated during the 0000 GMT forecast cycle is of limited value in record-breaking situations because the guidance is based on 48-h numerical model forecasts and tends to predict values closer to the normal.

In the results that follow, we examine the guidance as though it were valid for the nighttime rather than calendar day period. Our intention is to determine if the guidance warned of a record-breaking event. Nothing should be inferred from our discussion about the accuracy of the MOS temperature forecasts at all stations or over an extended period of record.

3. RESULTS

Tables 1, 2, and 3 show record-breaking min temperatures observed at 1200 GMT on December 24, December 25, and December 26, 1983, respectively. We've also included the observed departures from normal and the MOS min temperature forecasts produced approximately 24, 36, and 48 hours before the event. The algebraic errors (forecast minus observed) for the MOS guidance are given in parentheses after the forecast values.

On December 24, the record-breaking min temperatures given in Table 1 averaged nearly 30°F below normal. If we arbitrarily decide that a forecast within 2°F of the observed value is a prediction of the event, then the MOS guidance for tomorrow's min from 1200 GMT data accurately predicted record-breaking temperatures at Birmingham, San Angelo, Nashville, Fort Wayne, and Duluth. In fact, this guidance tended to have a distinct cold bias; the average mean algebraic error for those stations listed in Table 1 was -2.2°F! The MOS forecasts for tomorrow's min from 0000 GMT data and for the day after tomorrow's min from 1200 GMT data were biased towards warm values with mean algebraic errors of 1.2°F and 8.3°F, respectively. Nevertheless, record-breaking temperatures were predicted approximately 36 hours in advance at Waco, Peoria, Des Moines, Cheyenne, and Casper; from 48 hours in advance, the MOS forecasts were for record-breaking values at Wichita, Peoria, Des Moines, and Duluth. Note, too, that in terms of mean absolute error the guidance generally improved as the projection decreased.

Similar results can be seen for min temperatures observed on December 25 (Table 2). The MOS forecasts showed a pronounced warm bias for all three forecast projections although this bias declined dramatically from the day after tomorrow's min (1200 GMT) forecast to tomorrow's min forecast (1200 GMT). Note, too, the small mean absolute error for this latter forecast projection as the MOS guidance predicted record-breaking lows at Birmingham, New Orleans, Lake Charles, Shreveport, Brownsville, San Antonio, Victoria, Columbia, Charlotte, Nashville, Wichita Falls, Topeka, Peoria, Fort Wayne, and Omaha. Record-breaking values were predicted from the other two projections, although not so profusely as in the shorter range forecast.

The same pattern of accuracy occurs on December 26 (Table 3). The warm bias decreases sharply as the forecast projection becomes shorter. The guidance made for tomorrow's min temperature from 1200 GMT data is particularly accurate, predicting record-breaking values at Jacksonville, Atlanta, Shreveport, Brownsville, Waco, Columbia, Charlotte, Nashville, Memphis, Wichita Falls, and Philadelphia.

The LFM-analyzed 1000-500 mb thickness fields observed at 1200 GMT on December 24, December 25, and December 26 are shown in Figs. 4, 5, and 6, respectively. The LFM forecasts made 24, 36, and 48 hours in advance and valid for those times are also included. As indicated by the observed 552 dm contour, the cold air plunged deep into Texas on December 24, advanced into Florida by December 25, and reluctantly began to retreat from Texas by December 26. The LFM prognosis valid 48 hours in advance showed a distinct warm bias in Texas and the southeastern United States. The 36-h forecast was consistently colder than the 48-h prognosis valid at the same time. The 24-h prediction was colder than either the 36- or 48-h model output. Nevertheless, the 24-h LFM thickness forecasts were still too warm in Texas and the southeastern United States.

4. DISCUSSION

From the results presented in the previous section, several observations can be made about the MOS guidance. It is clear that the MOS temperature forecasts can and do predict record-breaking values. As shown, numerous minimum temperature records were shattered during the December 24 to December 26, 1983 period. Although the MOS guidance did not predict the majority of these events, some indication was given that unusual weather conditions would occur. Obviously, record-breaking events are rare in the MOS developmental sample. Nevertheless, it is tempting to speculate that on the synoptic scale the atmosphere is sufficiently well-behaved that a linear regression scheme like MOS shows skill in predicting events unavailable in the development. In other words, the MOS guidance can accurately forecast record-breaking temperatures at individual stations on specific days. This does not suggest, however, that the MOS errors averaged over a large number of stations will be small during periods when the atmospheric conditions deviate greatly from normal. On the contrary, another study (Murphy and Dallavalle, 1984) indicates that an increase in the overall temperature forecast errors tends to be associated with increasingly anomalous synoptic scale patterns.

As shown in Tables 1-3, the MOS forecasts usually improved as the length of projection decreased. Several reasons exist for this. First, as a general rule, the accuracy of the MOS guidance decreases with increasing projection. For example, in the developmental sample, the 24-h min temperature forecast equations fit the data more accurately than the 48-h min forecast equations. This is a natural result of the deterioration of the LFM forecasts with time. Consequently, for the longer range projections, the MOS forecasts tend toward a forecast of normal (as defined in the developmental sample) conditions. At the longer range projections in this study, the MOS guidance indicated below-normal temperatures, but not to the extent that actually occurred. This may simply be a limitation of the MOS technique. Secondly, as shown in Figs. 4-6, the 48-h LFM forecast persistently showed warm air moving back into Texas. As the valid time approached, the LFM forecasts for Texas and the southeastern United States became colder and the MOS forecasts followed this trend. Because the MOS guidance is driven by the LFM forecasts, it usually shows a direct relation to the model output. Finally, the shorter range MOS guidance relies strongly on surface observations as predictors. It is likely that the guidance for tomorrow's min from 1200 GMT data accounted for the extremely cold air that was influencing the area.

Since both the LFM and the MOS guidance had a warm bias at the 36- and 48-h projections, we might speculate whether the MOS forecasts would have been better with a more accurate LFM. We have not included details here, but Hlywiak and Dallavalle (1984) showed two cases during the 1983-84 winter where perfect LFM forecasts were used in the MOS equations. Their results showed some improvement in the MOS guidance, but not to an overwhelming degree. This is not too surprising. Since the MOS approach is designed to account for both systematic biases and the inherent inaccuracy of the numerical model, we would not expect the guidance to give perfect forecasts on any given day, even with perfect model output. To the extent that the MOS predictors represent real atmospheric relationships, the guidance would improve with a more accurate model. However, because the MOS equations are also providing a statistical correction, a more accurate model on a given day does not necessarily imply better statistical forecasts.

One final point needs to be mentioned. As alluded to previously, the MOS temperature forecast equations do not explain 100% of the temperature variance of the developmental sample. In other words, if we make forecasts from the guidance equations on the developmental data, we will find errors in the guidance. Part of this error is due to the inaccuracy of the LFM, but part is likely because of limitations in our predictors. Undoubtedly, we do not use every meteorological quantity that explains temperature variations. Primary physical quantities that come to mind are the surface moisture and temperature. We know that under summer drought conditions the MOS maximum temperature guidance has a cold bias (McCarthy, 1984) because most of the sun's energy is being converted into sensible heat, rather than the usual combination of sensible and latent heat. Likewise, we think the MOS guidance can go awry in the winter if soil conditions are unusual. Prior to the December 24-26, 1983 period, the soil temperature in Texas and the southeastern United States was probably substantially colder than normal because of earlier Arctic outbreaks. Moreover, the extensive snow cover to the north meant that the anticyclone moving southward during December 24 and 25 underwent less surface modification than normal. In fact, it is tempting to speculate that the errors in the LFM were due to inadequate representation of surface conditions. Nevertheless, it seems clear that the MOS temperature forecasts will be erroneous when surface conditions that impact the temperatures are extremely abnormal. Until observations of soil temperature and moisture are taken on a regular basis and can be included explicitly in the MOS development, this limitation on the accuracy of the guidance will continue to exist.

5. CONCLUSIONS

From this study, some guidelines can be established to help the forecaster use the guidance more effectively. As we have shown, during the December 24-26, 1983 period, the MOS min temperature guidance predicted a number of record-breaking values, particularly at the shorter ranges. An objective forecast of near- or record-breaking temperatures is a warning of the possibility of an extremely unusual event. The forecaster must know the local climatology, particularly regarding record-breaking temperatures. Secondly, the forecaster should remember that the MOS guidance is directly dependent on the LFM. If the LFM shows cooling (or warming), MOS will generally do likewise. If consistency or trends in the LFM guidance over several cycles indicate to the forecaster how the model should be modified, then similar reasoning should be applied to the interpretation of the MOS guidance. Thirdly, the forecaster must recognize that the MOS forecasts tend with increasing projection toward the normals because of inherent limitations in the accuracy of the LFM. A large forecast deviation from normal at these ranges must be considered carefully by the forecaster as a potential early warning signal. Similarly, during a cold air outbreak, the MOS guidance often predicts warming in the min temperature from the first period to the third period. This change must be viewed with caution since it may be reflecting the tendency of MOS to revert to normal conditions at the longer range projections. Finally, and, perhaps, most importantly, the forecaster must realize that ground conditions are only included implicitly in the MOS forecast equations. Significant deviations from normal in snow cover, soil moisture, or soil temperature can cause errors in the MOS temperature forecasts because the surface physical processes controlling the low-level temperature are not modeled explicitly by the MOS approach.

6. ACKNOWLEDGMENTS

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REFERENCES

Dallavalle, J. P., J. S. Jensenius, Jr., and W. H. Klein, 1980: Improved surface temperature guidance from the limited-area fine mesh model. Preprints Eighth Conference on Weather Forecasting and Analysis, Denver, Amer. Meteor. Soc., 1-8.

Hlywiak, K. P., and J. P. Dallavalle, 1984: Two case studies of MOS temperature forecast inconsistencies at Brownsville, Texas during the winter of 1983-1984. TDL Office Note, National Weather Service, NOAA, U.S. Department of Commerce, (in press).

McCarthy, D. H., 1984: The 1980 and 1983 heat waves in Missouri - temperature and rainfall patterns and temperature forecasts. Preprints Tenth Conference on Weather Forecasting and Analysis, Clearwater, Amer. Meteor. Soc., 75-77.

Murphy, M. C., and J. P. Dallavalle, 1984: An investigation of MOS minimum temperature errors in North and South Dakota during December 1982. TDL Office Note, National Weather Service, NOAA, U.S. Department of Commerce, (in press).

National Weather Service, 1980: Automated maximum/minimum temperature, 3-hourly surface temperature, and 3-hourly surface dew point guidance. NWS Technical Procedures Bulletin No. 285, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 16 pp.

______, 1983a: The FOUS12 (FO12) bulletin. NWS Technical Procedures Bulletin No. 325, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 12 pp.

______, 1983b: The FOUS22 (FO22) message. NWS Technical Procedures Bulletin No. 327, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 12 pp.

Table 1. Stations which observed record-breaking minimum temperatures at 1200 GMT, December 24, 1983. MOS forecasts (°F) verifying at that time and generated approximately 24 (tomorrow's min from 1200 GMT), 36 (tomorrow's min from 0000 GMT), and 48 (day after tomorrow's min from 1200 GMT) hours previously are also shown. The algebraic errors (forecast minus observed) for the guidance are given in parentheses. The observed departure from normal (D.N.) is also listed. The normals used were based on 1941-70 values.

Station	WMO Station No.	Observed Min	D.N.	Tomorrow's Min (1200 GMT)	Tomorrow's Min (0000 GMT)	Day after Tomorrow's Min (1200 GMT)
Birmingham, AL	228	15	-19	16 (1)	18 (3)	20 (5)
San Antonio, TX	253	16	-25	19 (3)	28 (12)	34 (18)
Victoria, TX	255	22	-23	25 (3)	25 (3)	38 (16)
Waco, TX	256	14	-24	10 (-4)	15 (1)	21 (7)
Dallas-Ft. Worth, TX	259	9	-27	5 (-4)	4 (-5)	17 (8)
Del Rio, TX	261	17	-21	29 (12)	29 (12)	36 (19)
San Angelo, TX	263	7	-27	9 (2)	18 (11)	29 (22)
Midland, TX	265	7	-24	12 (5)	15 (8)	31 (24)
Lubbock, TX	267	1	-25	-5 (-6)	13 (12)	8 (7)
Nashville, TN	327	3	-27	3 (0)	6 (3)	9 (6)
Wichita Falls, TX	351	6	-25	-2 (-8)	3 (-3)	11 (5)
Indianapolis, IN	438	-16	-37	-10 (6)	-9 (7)	-3 (13)
Wichita, KS	450	-7	-30	-18 (-11)	-18 (-11)	-9 (-2)
Topeka, KS	456	-12	-32	-23 (-11)	-25 (-13)	-17 (-5)
Chicago, IL	530	-24	-40	-19 (5)	-13 (11)	-17 (7)
Peoria, IL	532	-18	-36	-22 (-4)	-19 (-1)	-17 (1)
Fort Wayne, IN	533	-16	-35	-15 (1)	-13 (3)	-3 (13)
Des Moines, IA	546	-19	-34	-28 (-9)	-18 (1)	-20 (-1)
Omaha, NE	553	-20	-35	-30 (-10)	-23 (-3)	-17 (3)
Cheyenne, WY	564	-25	-41	-22 (3)	-25 (0)	3 (28)
Casper, WY	569	-34	-39	-40 (-6)	-32 (2)	-17 (17)
Aberdeen, SD	659	-24	-27	-33 (-9)	-33 (-9)	-32 (-8)
Rapid City, SD	662	-21	-34	-31 (-10)	-31 (-10)	-25 (-4)
Duluth, MN	745	-21	-24	-23 (-2)	-25 (-4)	-21 (0)
Mean Algebraic Error (°F)				-2.2	1.2	8.3
Mean Absolute Error (°F)				5.6	6.2	10.0

Table 2. Same as Table 1 except for minimum temperatures observed at 1200 GMT on December 25, 1983.

Station	WMO Station No.	Observed Min	D.N.	Tomorrow's Min (1200 GMT)	Tomorrow's Min (0000 GMT)	Day after Tomorrow's Min (1200 GMT)
Jacksonville, FL	206	11	-33	14 (3)	18 (7)	26 (15)
Charleston, SC	208	11*	-26	16 (5)	13 (2)	20 (9)
Tampa, FL	211	20	-30	25 (5)	27 (7)	41 (21)
Mobile, AL	223	8	-34	5 (-3)	10 (2)	24 (16)
Montgomery, AL	226	5	-32	11 (6)	18 (13)	22 (17)
Birmingham, AL	228	2	-32	3 (1)	7 (5)	12 (10)
New Orleans, LA	231	15	-29	16 (1)	21 (6)	34 (19)
Lake Charles, LA	240	13	-30	14 (1)	19 (6)	27 (14)
Shreveport, LA	248	7	-31	6 (-1)	17 (10)	14 (7)
Brownsville, TX	250	20	-32	22 (2)	41 (21)	44 (24)
San Antonio, TX	253	12	-28	11 (-1)	30 (18)	28 (16)
Austin, TX	254	10	-30	6 (-4)	17 (7)	25 (15)
Victoria, TX	255	14	-30	15 (1)	22 (8)	32 (18)
Waco, TX	256	10	-27	5 (-5)	14 (4)	16 (6)
San Angelo, TX	263	7	-27	15 (8)	17 (10)	26 (19)
Midland, TX	265	7	-23	19 (12)	15 (8)	21 (14)
Columbia, SC	310	7	-26	9 (2)	11 (4)	13 (6)
Charlotte, NC	314	4	-27	2 (-2)	9 (5)	10 (6)
Chattanooga, TN	324	-2	-33	2 (4)	8 (10)	7 (9)
Nashville, TN	327	-5	-35	-6 (-1)	-2 (3)	-4 (1)
Little Rock, AR	340	-1	-30	7 (8)	15 (16)	11 (12)
Wichita Falls, TX	351	5	-25	6 (1)	14 (9)	12 (7)
Washington, D.C.	405	3	-25	7 (4)	9 (6)	13 (10)
Evansville, IN	432	-7	-32	-1 (6)	-2 (5)	-3 (4)
St. Louis, MO	434	-13	-37	-5 (8)	-3 (10)	-4 (9)
Wichita, KS	450	-8	-30	-5 (3)	-4 (4)	1 (9)
Topeka, KS	456	-11	-30	-10 (1)	-14 (-3)	-12 (-1)
Chicago, IL	530	-17	-33	-13 (4)	-8 (9)	-14 (3)
Peoria, IL	532	-14	-31	-14 (0)	-12 (2)	-16 (-2)
Fort Wayne, IN	533	-12	-31	-14 (-2)	-9 (3)	-12 (0)
Detroit, MI	537	-10	-31	-3 (7)	-5 (5)	-3 (7)
Omaha, NE	553	-17	-31	-15 (2)	-13 (4)	-16 (1)
Rapid City, SD	662	-26	-38	-13 (13)	-8 (18)	-16 (10)
Mean Algebraic Error (°F)				2.7	7.4	10.0
Mean Absolute Error (°F)				3.8	7.6	10.2

*The observed minimum temperature at CHS was taken from an archive of hourly reports and did not correspond to that reported in Fig. 2.

Table 3. Same as Table 1 except for minimum temperatures observed at 1200 GMT on December 26, 1983.

Station	WMO Station No.	Observed Min	D.N.	Tomorrow's Min (1200 GMT)	Tomorrow's Min (0000 GMT)	Day after Tomorrow's Min (1200 GMT)
Jacksonville, FL	206	13	-31	14 (1)	18 (5)	27 (14)
Savannah, GA	207	17	-21	11 (-6)	13 (-4)	20 (3)
Atlanta, GA	219	5	-28	7 (2)	15 (10)	23 (18)
Montgomery, AL	226	8	-29	16 (8)	23 (15)	29 (21)
Birmingham, AL	228	6	-28	10 (4)	16 (10)	30 (24)
New Orleans, MS	231	18	-26	22 (4)	32 (14)	38 (20)
Meridian, MS	234	10	-25	13 (3)	23 (13)	23 (13)
Shreveport, LA	248	14	-24	13 (-1)	21 (7)	28 (14)
Brownsville, TX	250	28	-24	28 (0)	43 (15)	52 (24)
San Antonio, TX	253	15	-25	20 (5)	28 (13)	36 (21)
Austin, TX	254	15	-25	19 (4)	22 (7)	31 (16)
Victoria, TX	255	18	-26	25 (7)	30 (12)	41 (23)
Waco, TX	256	17	-20	19 (2)	23 (6)	25 (8)
San Angelo, TX	263	16	-18	26 (10)	30 (14)	37 (21)
Abilene, TX	266	15	-18	20 (5)	32 (17)	34 (19)
Columbia, SC	310	7	-26	7 (0)	7 (0)	23 (16)
Charlotte, NC	314	6	-25	5 (-1)	7 (1)	21 (15)
Chattanooga, TN	324	4	-26	8 (4)	10 (6)	25 (21)
Nashville, TN	327	2	-28	2 (0)	11 (9)	17 (15)
Memphis, TN	334	9	-23	11 (2)	20 (11)	23 (14)
Wichita Falls, TX	351	13	-17	15 (2)	15 (2)	21 (8)
Philadelphia, PA	408	3	-22	4 (1)	3 (0)	6 (3)
Charleston, WV	414	1	-25	-2 (-3)	-3 (-4)	9 (8)
Chicago, IL	530	-11	-27	-2 (9)	-2 (9)	2 (13)
Detroit, MI	537	-8	-29	1 (9)	-1 (7)	3 (11)
Mean Algebraic Error (°F)				2.8	7.8	15.3
Mean Absolute Error (°F)				3.7	8.4	15.3

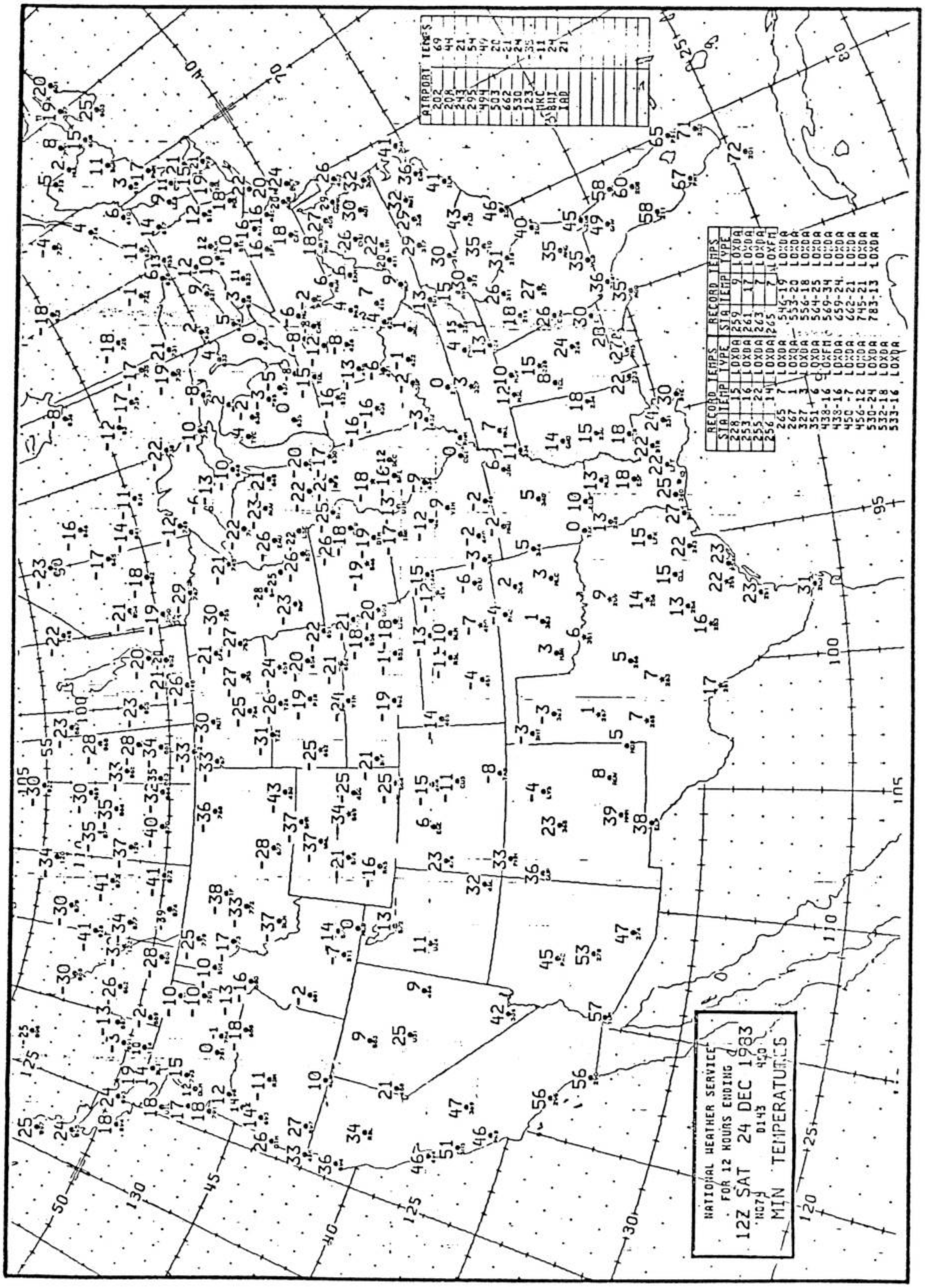

Figure 1. Minimum temperatures observed 1200 GMT, December 24, 1983.

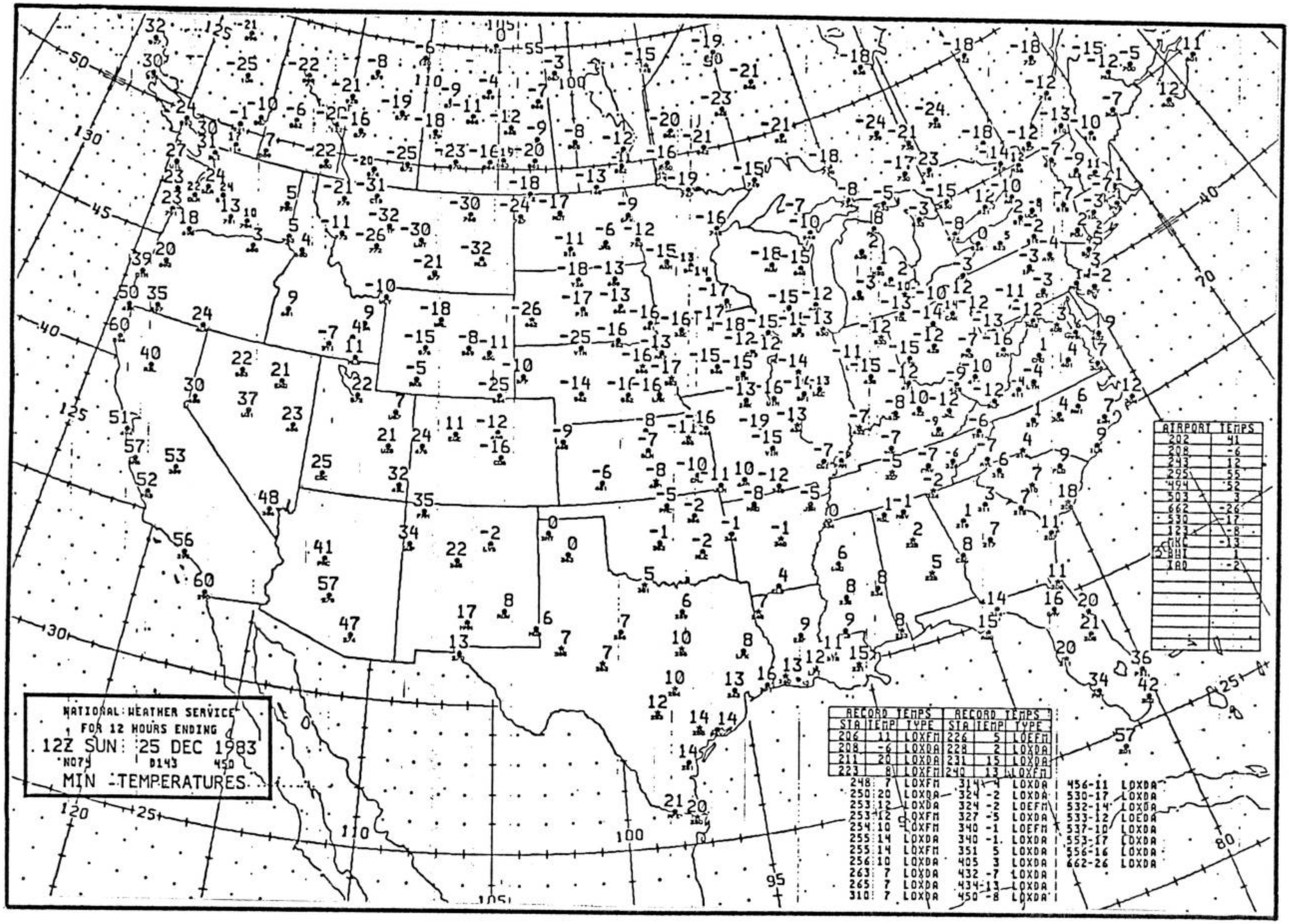

Figure 2. Same as Fig. 1 except for December 25, 1983.

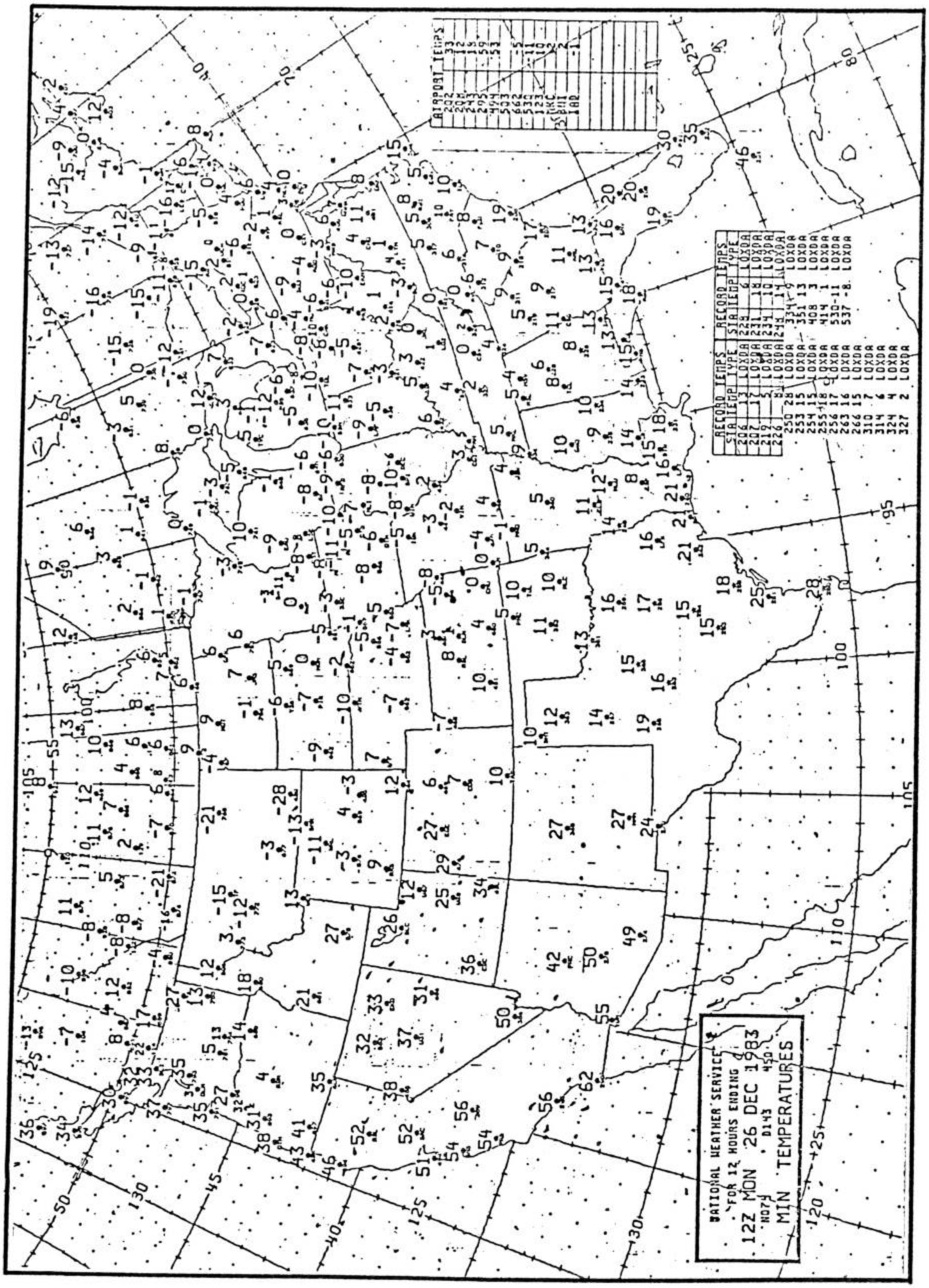

Figure 3. Same as Fig. 1 except for December 26, 1983.

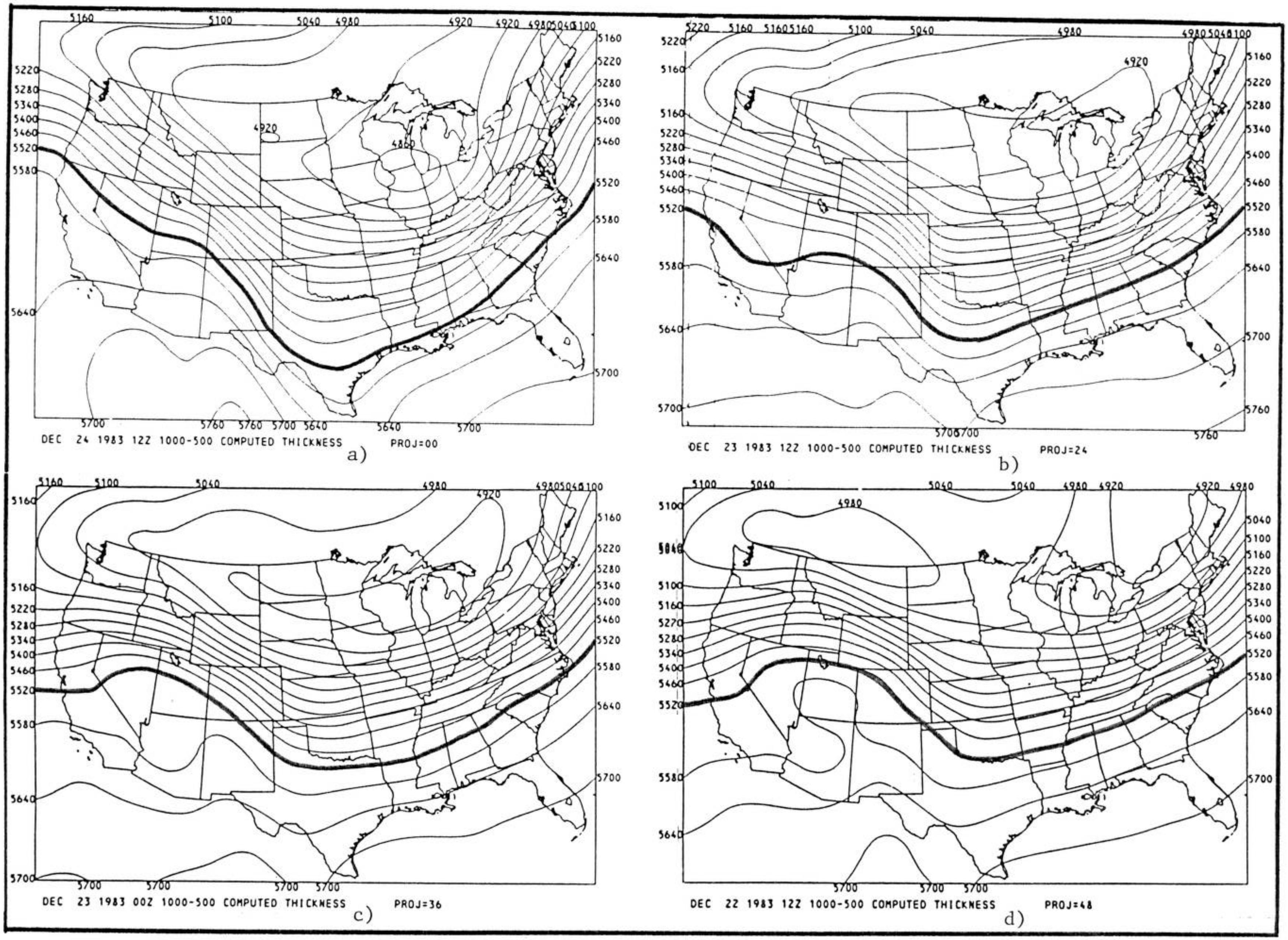

Figure 4. The LFM initial analysis (a) and the 24-h (b), 36-h (c), and 48-h (d) LFM forecasts of 1000-500 mb thickness valid 1200 GMT, December 24, 1983. The 5520 m contour is highlighted.

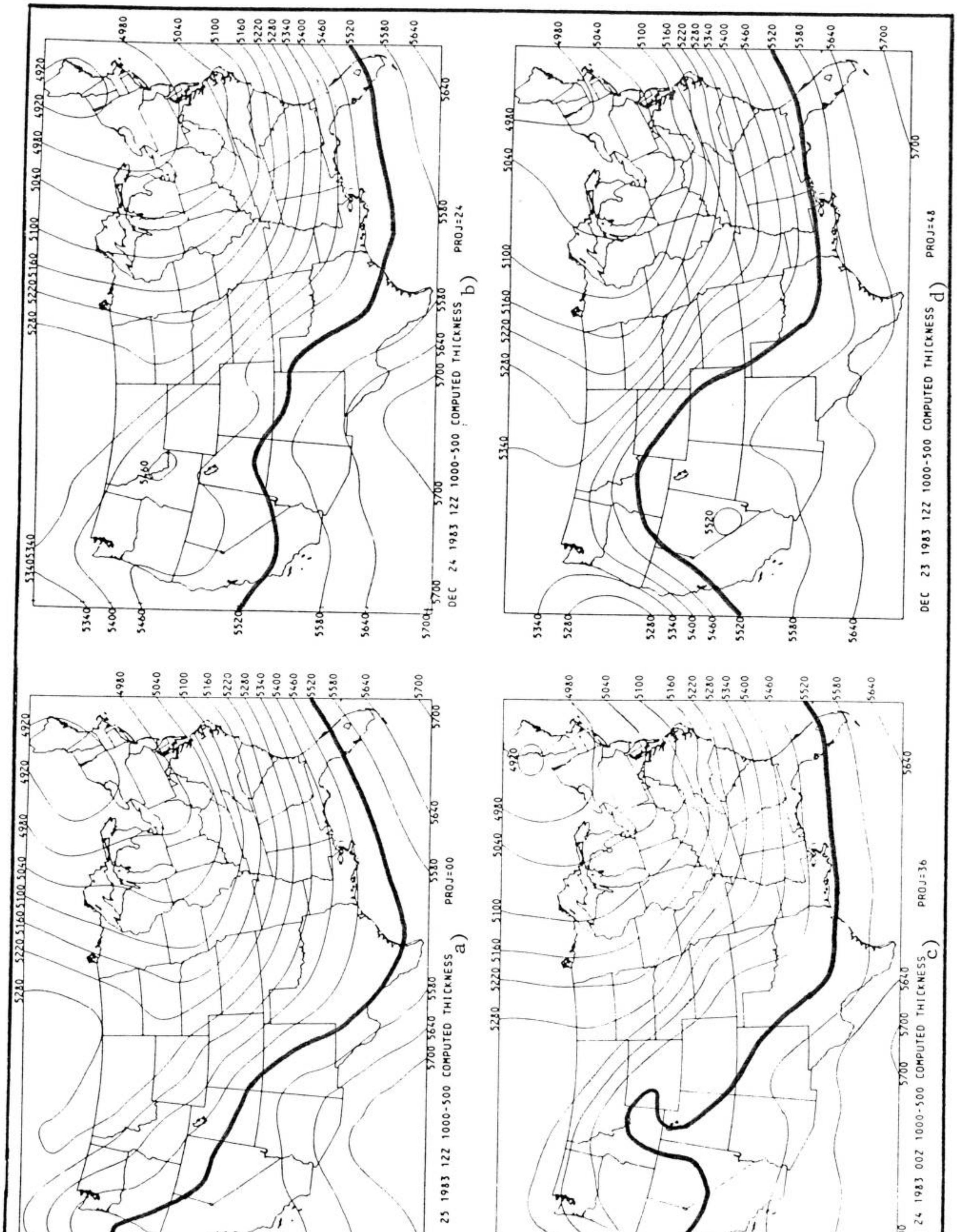

Figure 5. Same as Fig. 4 except for 1200 GMT, December 25, 1983.

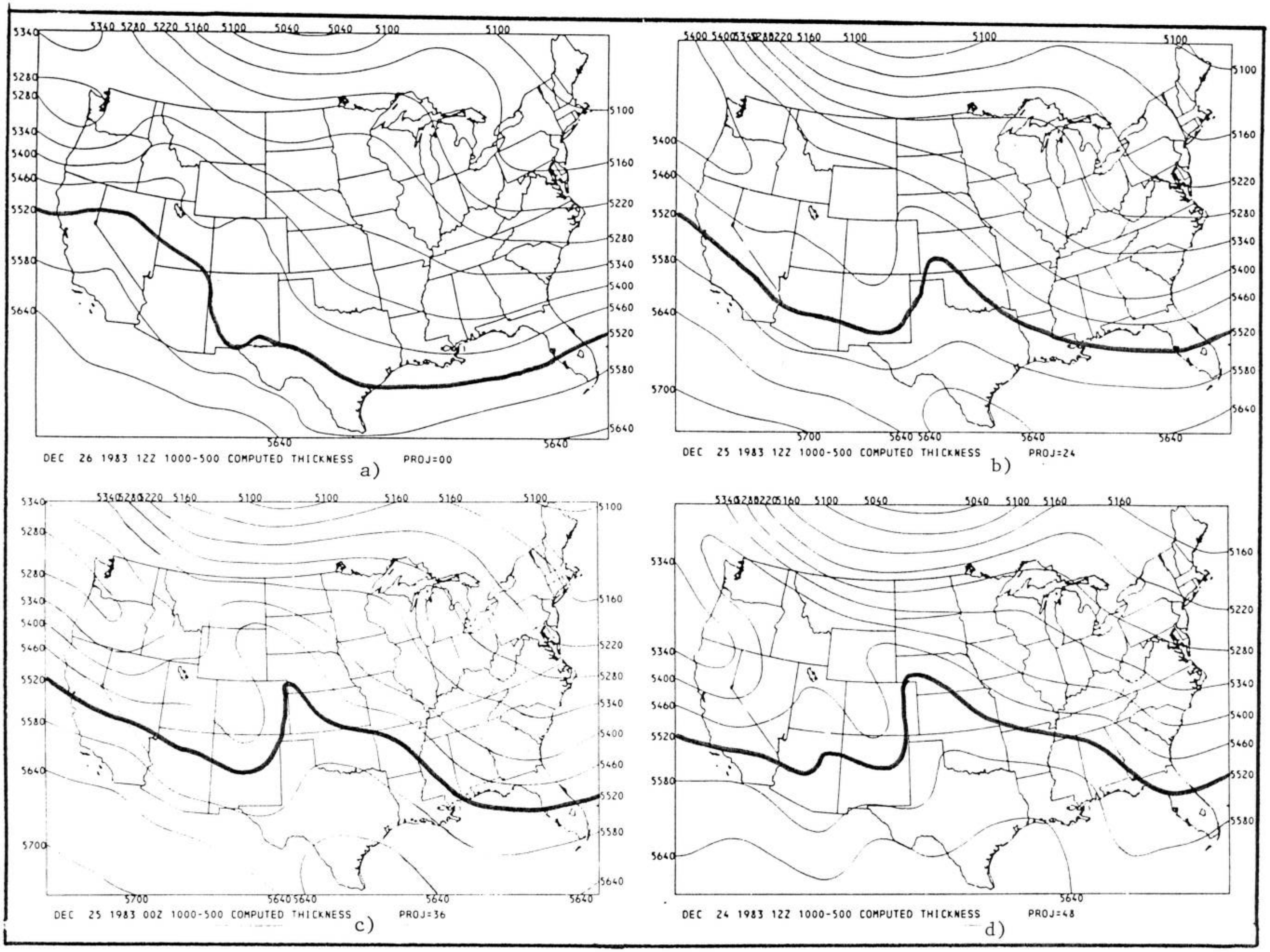

Figure 6. Same as Fig. 4 except for 1200 GMT, December 26, 1983.