FORECASTING

AN INTENSE HEAT CHECKLIST BASED ON THE 1980 HEAT WAVE

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ABSTRACT

An intense heat checklist is presented which can be used as an operational forecasting tool in predicting summer maximum temperatures. The checklist is developed through a study of the surface and upper air synoptic features of the heat wave of 1980. These synoptic features are compared to the geographic location of the warmest maximum temperatures. By using the checklist, the forecaster can determine the strength of subsidence over the forecast area, and predict maximum temperatures independent of model output statistics.

1. INTRODUCTION

The heat wave of 1980, one of the worst in modern history in both magnitude and duration in Texas, was responsible for at least 60 deaths in the state, and nearly 1300 deaths nationwide. Heat wave fatalities far outnumbered fatalities from other weather phenomena. Across the United States in 1980, there were 76 deaths due to lightning, 62 as a result of flash floods, and 28 from tornadoes (Storm Data, 3, 4). The heatwave in South Texas alone was blamed for 250 million to 500 million dollars in livestock and crop losses (Bomar, 5). Across the nation, losses were estimated at 16 billion dollars (Karl and Quayle, 6).

In this article, a discussion of a climatological normal summer for north Texas is presented, followed by some statistics of the summer of 1980. The mean circulation for each month (June through September) of the heat wave of 1980 is presented. Papers for additional information on this subject are suggested.

Next, the surface and upper air features of the 1980 heat wave are discussed in an attempt to find synoptic scale features that may be used in forecasting extremely hot days (105° F or greater). Finally, a checklist is included to aid forecasters in predicting summer maximum temperatures.

2. CLIMATOLOGY

North Texas summertime daily high temperatures average in the mid to upper 90s for much of June, July, and August. The hottest maximum temperatures at Dallas/Fort Worth typically occur in late July and early August with normal highs of 99°. At Abilene and Waco, the hottest maximums are usually in early August when high temperatures average 97° and 98°, respectively. Days with maximum temperatures of 100° or more are not unusual in north Texas with Wichita Falls averaging 34 days per year, Waco with 22 days, Dallas/Fort Worth with 21 days, and Abilene with 17 days.

The summer of 1980 was notable in both the duration of the heat wave and the extremely hot temperatures that were recorded. Table 1 shows the duration of the heat wave as well as the highest temperatures recorded in 1980 across north Texas. As indicated in Table 1, the 1980 heat wave in north Texas was very long in duration. High temperatures of 100° or more were recorded on more than 60 days. In a normal summer, temperatures reach 100° or more on 17–22 days, except in the Wichita Falls area (36 days).

The 113° recorded at Dallas/Fort Worth on June 26–27th was the all time high temperature ever observed at Dallas/Fort Worth, as was the 117° reached on June 28th at Wichita Falls. The hottest temperature observed in north Texas during the summer of 1980 was at Weatherford where the town blistered under 119° heat on June 26th. In addition, Dallas/Fort Worth set 32 daily record highs during the heat wave.

What caused the heat wave? Was it dominated by large-scale circulation patterns, or did smaller synoptic scale meteorological conditions have an effect? Hemispheric-scale circulation patterns were important in the long-term heat wave, but specific locations of intense heat were governed by smaller synoptic meteorological features.

3. MEAN CIRCULATION FOR THE SUMMER OF 1980

Large-scale circulation patterns for June, July, August, and September of 1980 have been discussed in Dickson (7), Livezey (8), Taubensee (9), Wagner (10), and Karl and Quayle (6). Mean 700-mb contours for June through September 1980 are shown in Figure 1. In June, as the westerlies migrated northward, a strong ridge built over the southeastern and south central United States. It has been documented that to sustain a large-scale heat wave-producing ridge over the central United States, accompanying above normal high-pres-

Table 1. Climatological data on 100°F days in north Texas.

	Dallas/ Ft. Worth	Wichita Falls	Abilene	Waco
Total 1980 >99° F days	69	79	42	63
Normal >99° F days	21	36	17	22
Consecutive 1980 >99° F days	42	42	12	42
Highest temp recorded 1980	113	117	109	109

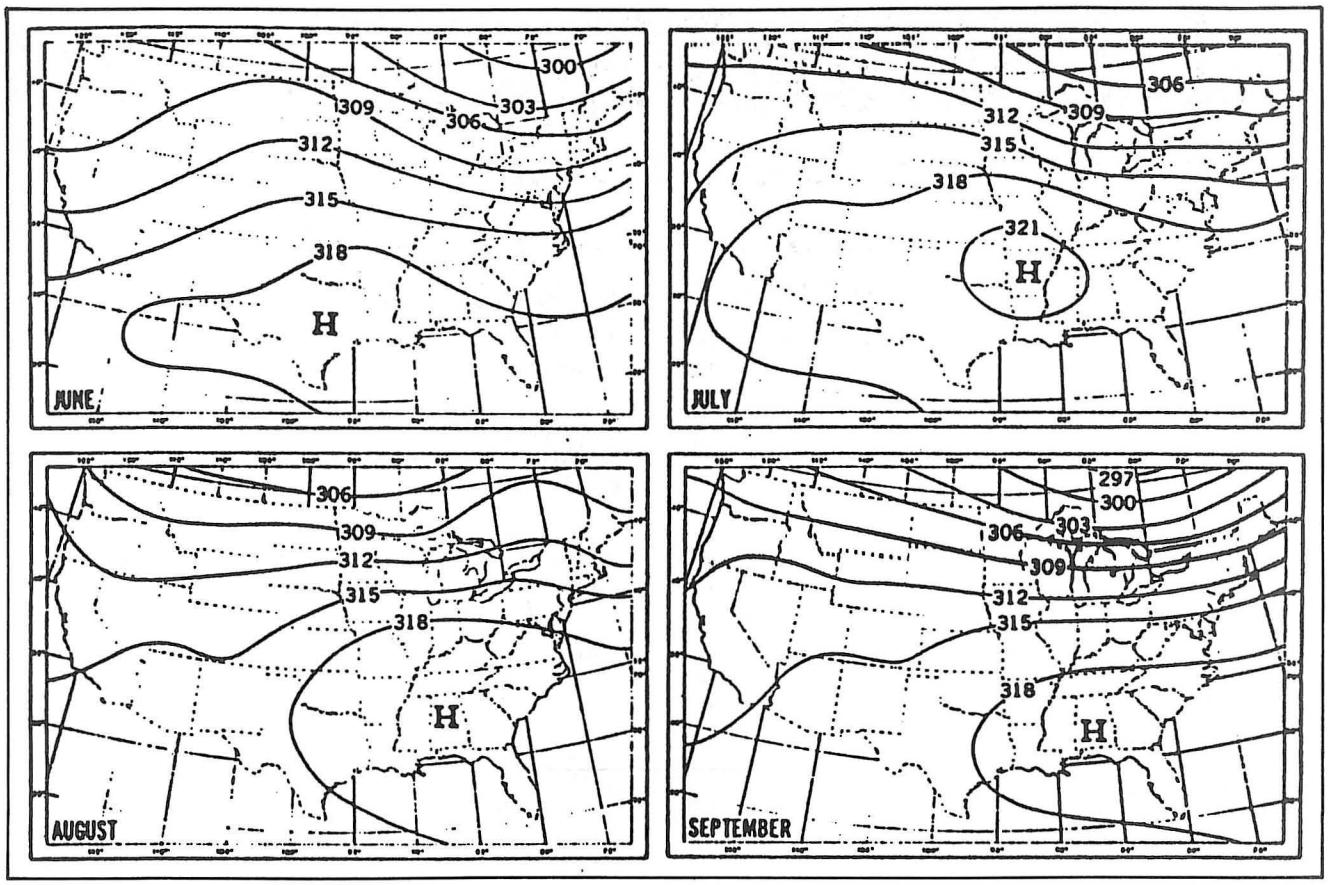

Fig. 1. Monthly mean 700-mb height contours (dam) for 1980.

sure areas are needed over the Atlantic and Pacific Oceans (Namias, 11).

The large-scale 700-mb High strengthened over the south central United States in July as strong oceanic Highs continued. Several north Texas cities recorded high temperatures over 100° every day in July. In August, the high-pressure cell over the south central United States weakened somewhat, and was displaced eastward as a 700-mb trough became predominate over the western United States. During September, as the westerlies moved south, the 700-mb ridge weakened and moved farther southeast, and the heat wave in north Texas abated.

Although hemispheric-scale high-pressure areas were present during the heat wave of 1980, smaller synoptic scale meteorological conditions were important in determining where hottest daily maximum temperatures occurred.

4. SYNOPTIC SCALE ASPECTS OF THE 1980 HEAT WAVE

An inspection of the daily upper air and surface charts from June through September of 1980 revealed several features that, if occurring simultaneously, would result in extremely high temperatures for a local area. Figures 2 through 5 show composite upper air synoptic patterns associated with intense heat during the summer of 1980. Figures 6 and 7 indicate two composite surface patterns. These composite maps were developed from the 20 hottest days of the summer of 1980. Dashed lines on these charts depict areas with hottest maximum surface temperatures. On the upper air maps, the solid lines are height contours in meters. On the surface charts, solid lines are isobars with fronts and troughs depicted by the usual convention.

At 300 mb (Fig. 2), the hottest temperatures generally occurred in the north to southeast parts of the 300-mb High. This is consistent with previous research which shows that convergence in the upper levels occurs on the east side of the upper level ridge (Palmen and Newton, 12). The convergence aloft indicates that subsidence would be present in the air column below the convergent area. However, high surface temperatures occurred underneath the entire High at 300-mb.

At 500 mb (Fig. 3), a large High was located over the southern U.S. during the siege of heat. In general, the 500-mb High was found not to be as good a predictor of highest maximum temperatures as features at other levels in the atmosphere.

The center of the high-pressure area at 700 mb (Fig. 4) was the best predictor of the location of highest surface temperatures. The hottest surface temperatures, indicating the greatest subsidence, occurred almost directly under the 700-mb High center.

At 850 mb (Fig. 5), hottest surface temperatures generally occurred between the 850-mb High center and a weak trough to the north or west. The highest 850-mb temperatures at 1200 GMT were found to be a good indicator of the location and magnitude of the hottest surface temperatures for that day.

Two surface patterns were found to prevail with intense heat conditions. The first pattern (Fig. 6) was a synoptically

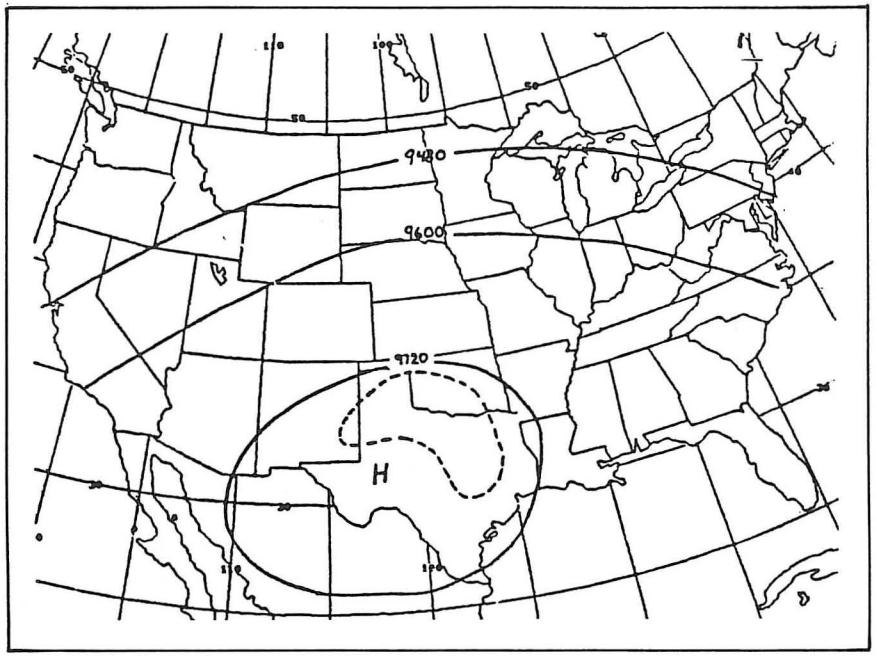

Fig. 2. 300-mb chart

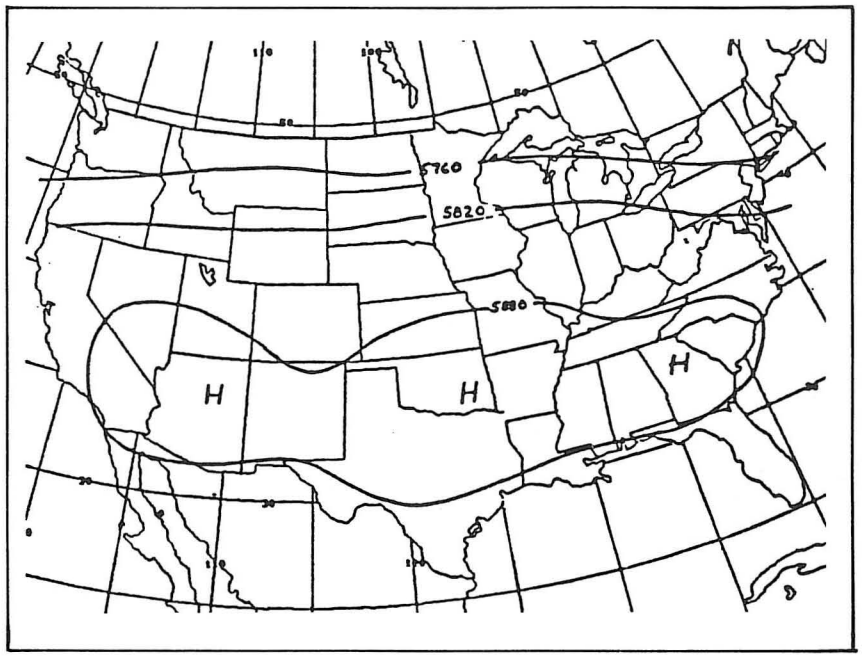

Fig. 3. 500-mb chart

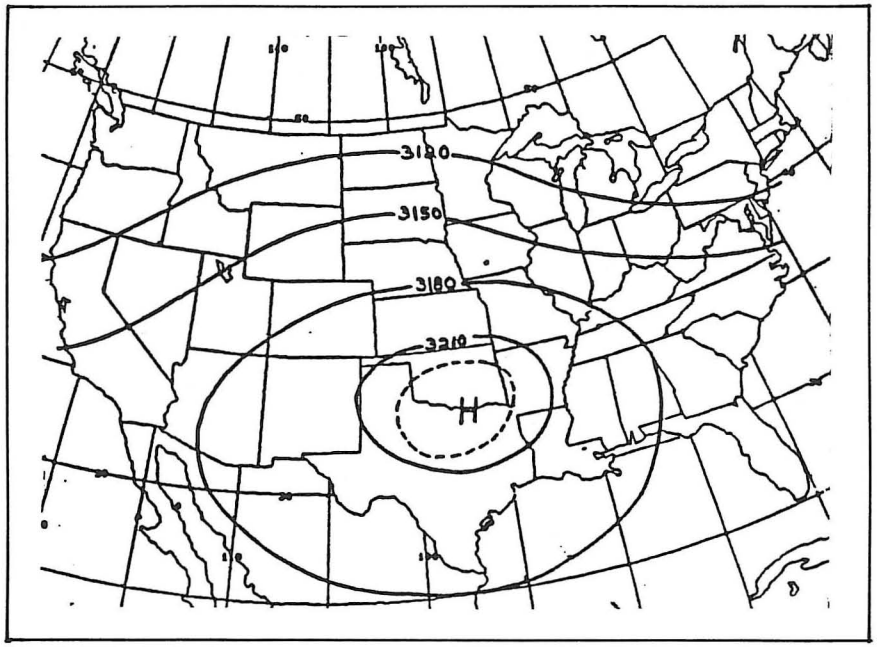

Fig. 4. 700-mb chart

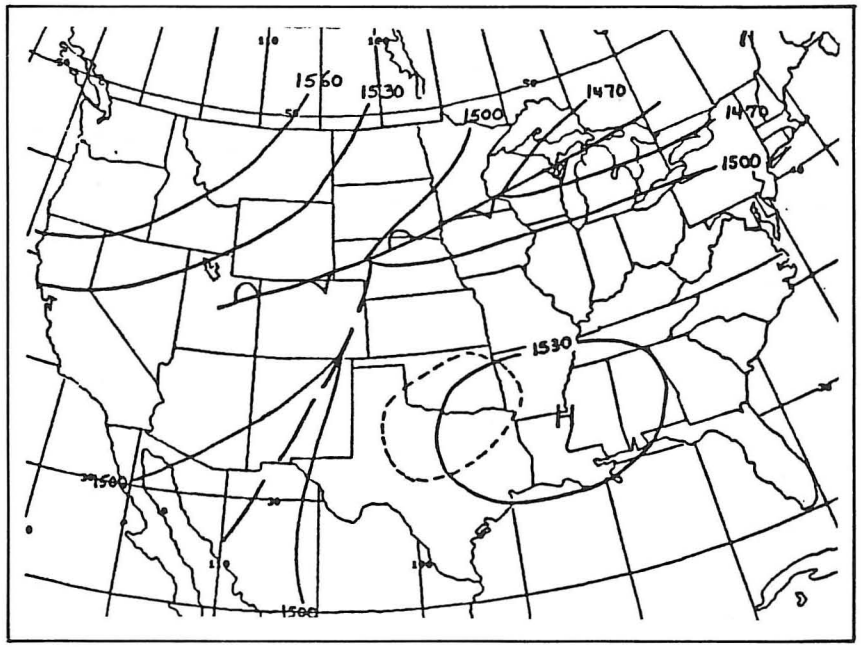

Fig. 5. 850-mb chart

Solid lines—height contours in meters. Dashed line—outlines area of hottest SFC temperatures.

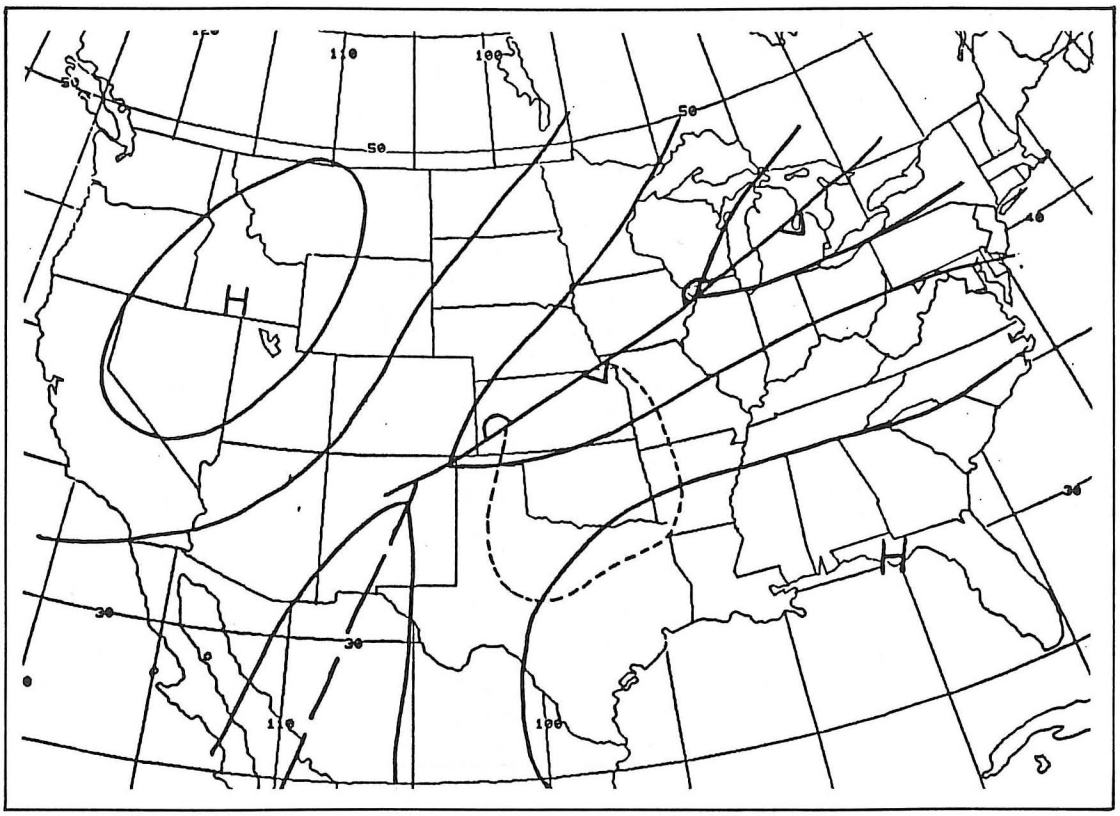

Fig. 6. Surface chart 1, surface ridge type.

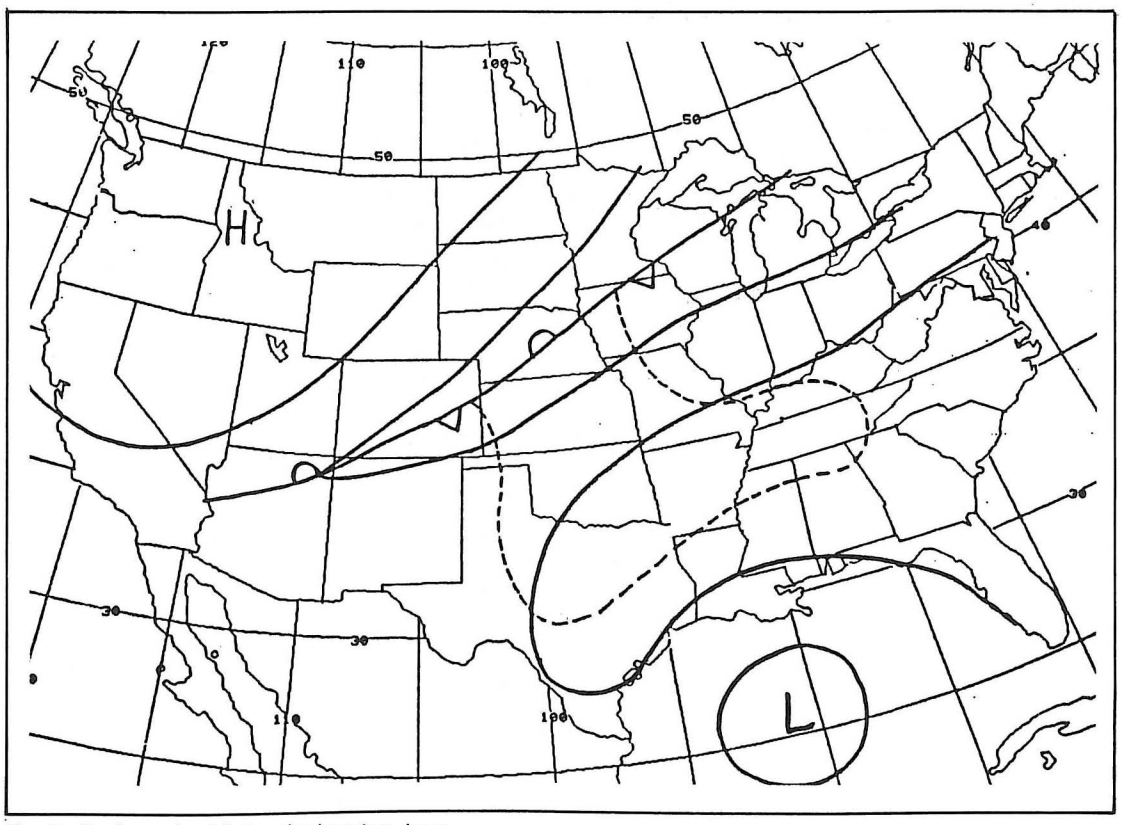

Fig. 7. Surface chart 2, tropical system type.

Solid lines—isobars
Dashed line—outlines area of hottest temperatures.

induced heat-wave pattern. This heat wave generally occurred north or northwest of a surface ridge along and just ahead of a surface cool front. For this type of intense heat to occur, the upper air pattern presented in Figures 2–5 should accompany this surface pattern.

The second surface pattern depicts a heat wave induced by a tropical system in the Gulf of Mexico (Fig. 7). The hottest surface maximum temperatures with this pattern generally occur in the anticyclonic flow 300 to 800 miles to the west through northeast of a closed tropical system in the Gulf of Mexico. If a surface trough is present over the central United States, the hottest temperatures will be along and to the south of this trough.

Surface dew-point temperatures were found not to be an inhibiter of very hot temperatures, but the depth of the low-level moisture in the atmosphere did inhibit heating somewhat. The afternoon sea breeze along the Gulf of Mexico limited afternoon heating in coastal areas.

5. DISCUSSION OF CAUSES OF INTENSE WARMING

Factors that can cause intense warming in low-levels of the atmosphere are advection of warm air, synoptic scale subsidence, and terrain-induced downslope flow. Warm-air advection was not a major factor in the 1980 summer intense heat events. The intense warming was the result of subsidence, possible enhanced by downslope flow. This leads to the difficult task of forecasting the maximum subsidence area.

It was found, after an inspection of the daily surface and upper air charts from the summer of 1980, that the 300-mb and 700-mb levels were the best indicators of where strong subsidence was occurring. The area just to the northeast of the 300-mb High, and the area directly beneath the 700-mb High were found to be the most preferred locations of the maximum surface temperatures (Figs. 2 and 4).

These upper air patterns were usually accompanied by the surface pattern depicted in Figure 6, where intense warming occurred along and within 500 miles south of a frontal boundary. This weather scenario and accompanying heat wave was noted to occur over the southern and central plains east of the Rockies, as well as over most of the Mississippi and Ohio Valley areas of the United States.

The second surface heat-wave pattern (Fig. 7) was a short-lived event that frequently occurred in the anticyclonic flow area created over the southern plains and the Mississippi Valley area by a closed tropical system in the central or western Gulf of Mexico. The intense heat usually occurred along and northwest through northeast of the ridge line over the southern United States. This type of event (Fig. 7) normally only lasted a day or two. Synoptic episodes depicted in Figure 6 lasted several weeks.

6. INTENSE HEAT CHECKLIST

From the evaluation of the weather data from 1980, an intense heat checklist has been developed to aid in forecasting summer maximum temperatures. This checklist is shown in Table 2(a). The items in this table are usually readily available to forecasters.

Ideally, the data used in the checklist should be from the morning (1200 GMT) upper air plots and surface maps. Normally in summer, no large change in the data is going to occur within 12 hr. A forecast up to two days in advance can be made by using estimated data from numerical models.

Table 2(a). INTENSE HEAT CHECKLIST

	Strong	Moderate	Weak
1. 300-mb anticyclonic flow over area	Yes	Neutral	No
2. Location of area in relation to 300-mb high center	N-SE	S-NW	Greater than 500 mi from center
3. 500-mb wind speed (knots)	Less than 20	20–30	Greater than 30
4. 500-mb anticyclonic flow over area	Yes	Neutral	No
5. Location of area in relation to 700-mb high center (miles)	Less than 300	300–500	Greater than 500
6. 700-mb anticyclonic flow over area	Yes	Neutral	No
7. 850-mb wind direction	S-W	E-SE	NW-NE
8. 850-mb anticyclonic flow over area	Yes	Neutral	No
9. Estimated depth of low level moisture from sounding	Sfc to below 900-mb	Sfc to below 800 mb but above 900-mb	Sfc to above 800-mb
10. Surface wind direction	SE-W	NE-E	NW-N
**11. Surface NE-SW front within 500 mi NW to N of area	Yes	No	
-or-			
Closed tropical system in Gulf with anticyclonic flow over area	Yes	No	

**NOTE on #11: Either or both "yes" = 1 pt strong
Both "no" = 1 pt moderate

To use the checklist a forecaster should circle one answer for each line that applies to the factor listed on the left of the table. The items in the checklist are self-explanatory. The "area" referred to in some of the items is the local forecast area, and could even be a single station. The estimated depth of low-level moisture in item 9 is a subjective judgement by the forecaster determined from a sounding close to the area. The importance of this factor is that the deeper the moisure is in the low-levels, the more heating is going to be inhibited. The surface scenarios described in item 11 are depicted in Figures 6 and 7. As noted on the checklist, if either one or both of these surface scenarios is present, count one point toward a strong event. If neither of these scenarios is present, count one point toward a moderate event.

The forecaster should evaluate if the checklist indicates strong, moderate, or weak subsidence by counting the number of factors under each heading. In general, the strength of the event would be the category (strong, moderate, weak) that has the most factors present. A weak factor would tend to cancel out a strong one. No attempt will be made to forecast maximum temperatures for a weak event, since intense heat is not likely to occur if several of the weak factors are present.

If the event is determined to be strong or moderate, the forecasters would next look at Table 2(b) or Table 2(c), which forecast maximum temperatures by using 850-mb 1200 GMT observed temperatures. Table 2(b) is used for locations from near sea level up to 1200 ft above sea level. Table 2(c) is used for locations that are 1200 to 2200 ft above sea level. No attempt will be made to forecast maximum temperatures for locations higher than 2200 ft above sea level.

These tables include a forecast for both strong and moderate events. If the event is thought to be a borderline strong to moderate case, the forecaster can interpolate between the expected temperatures of the two categories on the table. The "max" line under the strong category shows the highest surface temperatures recorded for the corresponding 850-mb 1200 GMT temperature range in north Texas from 1980 to 1987. This checklist should only take a couple of minutes of the forecaster's time to complete.

7. AN EXAMPLE OF USING THE CHECKLIST—JUNE 8, 1988

The checklist was applied to the 1200 GMT data for June 8, 1988 to calculate daytime maximum temperatures. Intense warming occurred over southwest Oklahoma and the western part of north Texas that day. Maximum temperatures recorded for June 8th were well above the century mark. The 1200 GMT upper air and surface maps for this case are shown in Figures 8–12.

Inspecting the factors in the checklist using the 1200 GMT data for June 8, 1988 revealed that for southwest Oklahoma and the western part of north Texas, 9 of the factors were strong, 2 were moderate, and none were weak. This indicated that strong subsidence would likely occur over these areas during the day. The 1200 GMT 850-mb temperature over southwest Oklahoma was estimated to be 26°C, with 24°C at Wichita Falls, TX., 25°C at Abilene, TX. The forecast high temperatures for the afternoon were estimated from Tables 2(b) and 2(c). For southwest Oklahoma, high temperatures were forecast to be 108°–110°F using Table 2(b), and for the Wichita Falls area (994 ft MSL elevation), 104°–106°F. For Abilene, high temperatures of 100°–102°F were forecast, using Table 2(c) because of the higher elevation of Abilene (1784 ft MSL elevation).

Observed maximum temperatures for June 8, 1988 are shown in Figure 13. As can be seen from Figure 13, observed maximum temperatures for southwest Oklahoma were 108°–111°F, with 105°F at Wichita Falls, TX, and 103°F at Abilene, TX.

Comparatively, the model output statistics (MOS) for the 1200 GMT LFM run on June 7, 1988 forecasted (second period) high temperatures for June 8, 1988 of 99°F at Hobart, OK; 99°F at Wichita Falls, TX; and 98°F at Abilene, TX. The MOS for the 0000 GMT LFM run June 8, 1988 was only slightly better with forecasted (first period) high temperatures of 99°F at Hobart, 100°F at Wichita Falls, and 99°F at Abilene. High temperatures forecasted from the checklist were much closer to the observed high temperatures than the MOS projections.

SURFACE HIGH TEMPERATURES PREDICTED FROM 850 MB TEMPERATURES

Table 2(b). For station elevations 0 to 1200 ft above sea level.

	850-mb temperature (C)				
	18–19	20–22	23–25	26–29	30–32
Strong	92–96	97–103	101–106	107–111	111–116
	max 100	max 106	max 110	max 114	max 119
Moderate	87–92	94–98	97–101	101–106	107–111

Forecasted high temperatures (F)

Table 2(c). For station elevations 1200 to 2200 ft above sea level.

	850-mb temperature (C)				
	18–19	20–22	23–25	26–29	30–32
Strong	87–92	93–98	96–101	102–106	106–110
	max 95	max 100	max 105	max 110	max 113
Moderate	83–88	88–93	92–96	97–102	103–107

Forecasted high temperatures (F)

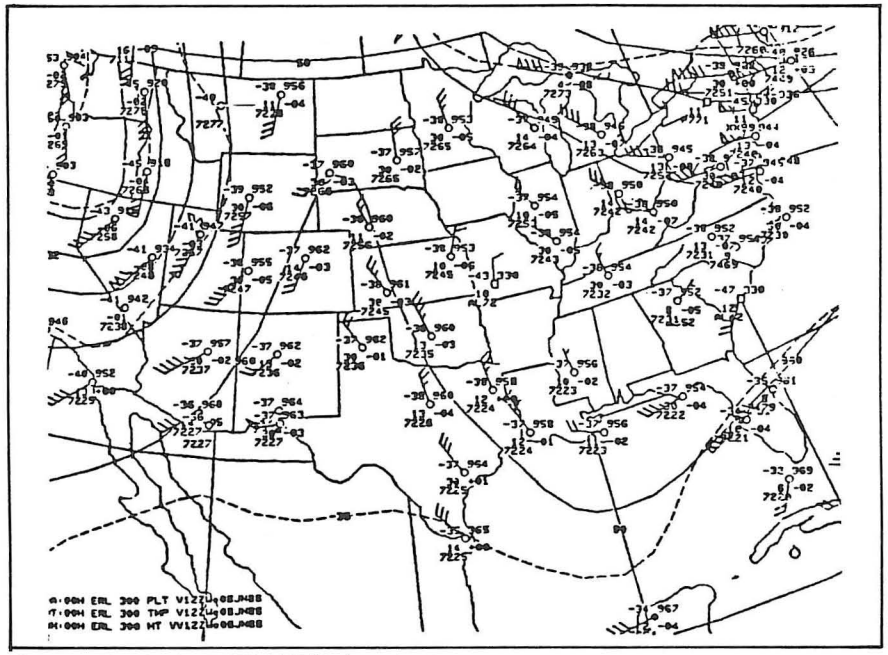

Fig. 8. 300-mb chart 1200 GMT, June 8, 1988

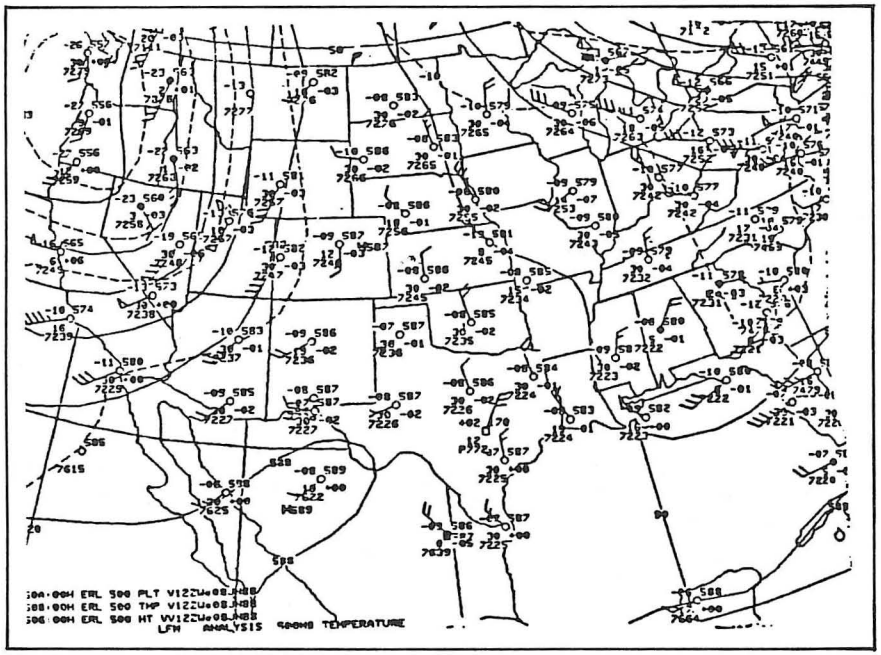

Fig. 9. 500-mb chart 1200 GMT, June 8, 1988

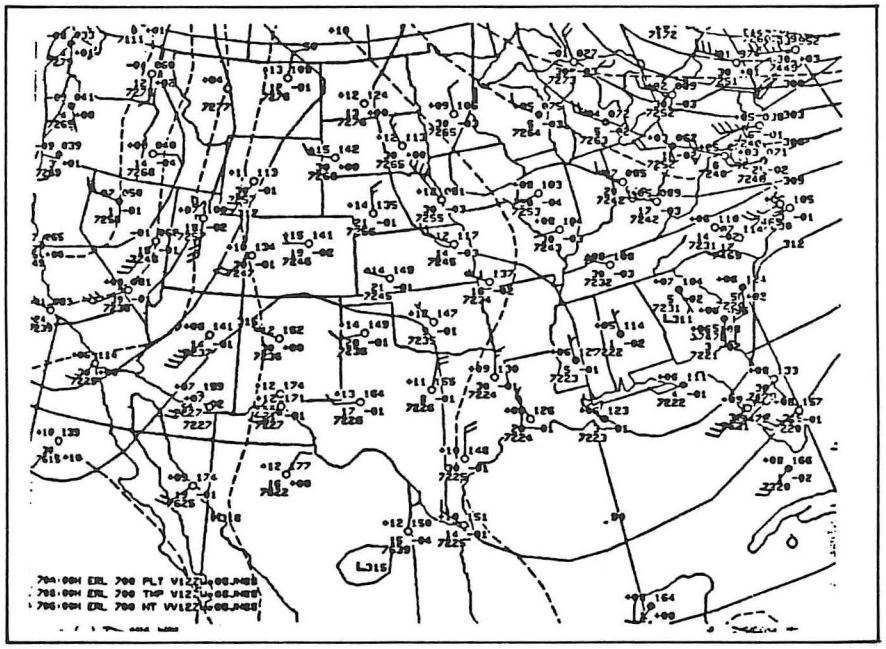

Fig. 10. 700-mb chart 1200 GMT, June 8, 1988

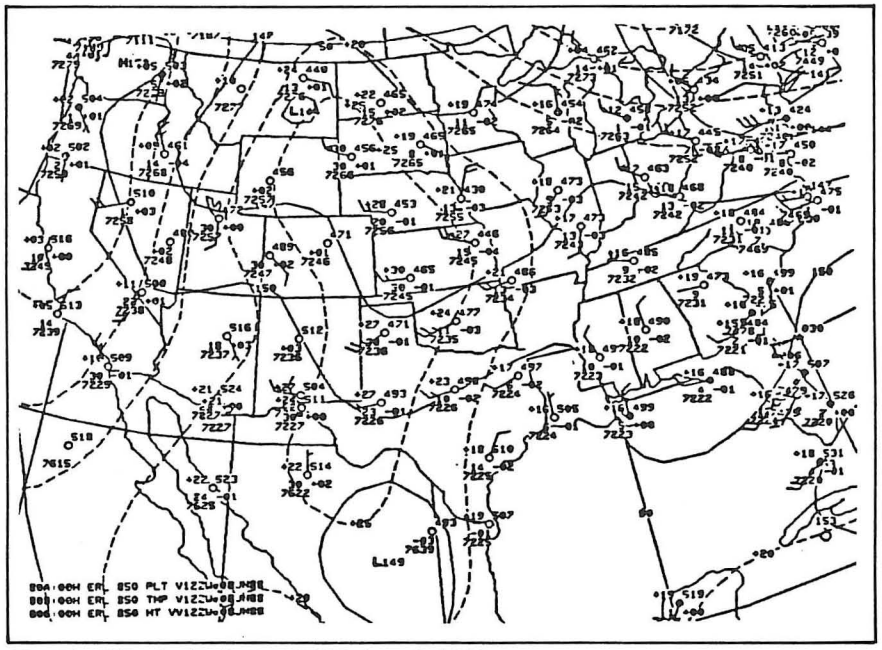

Fig. 11. 850-mb chart 1200 GMT, June 8, 1988

Solid lines—height contours **Dashed lines—isotherms (°C)**

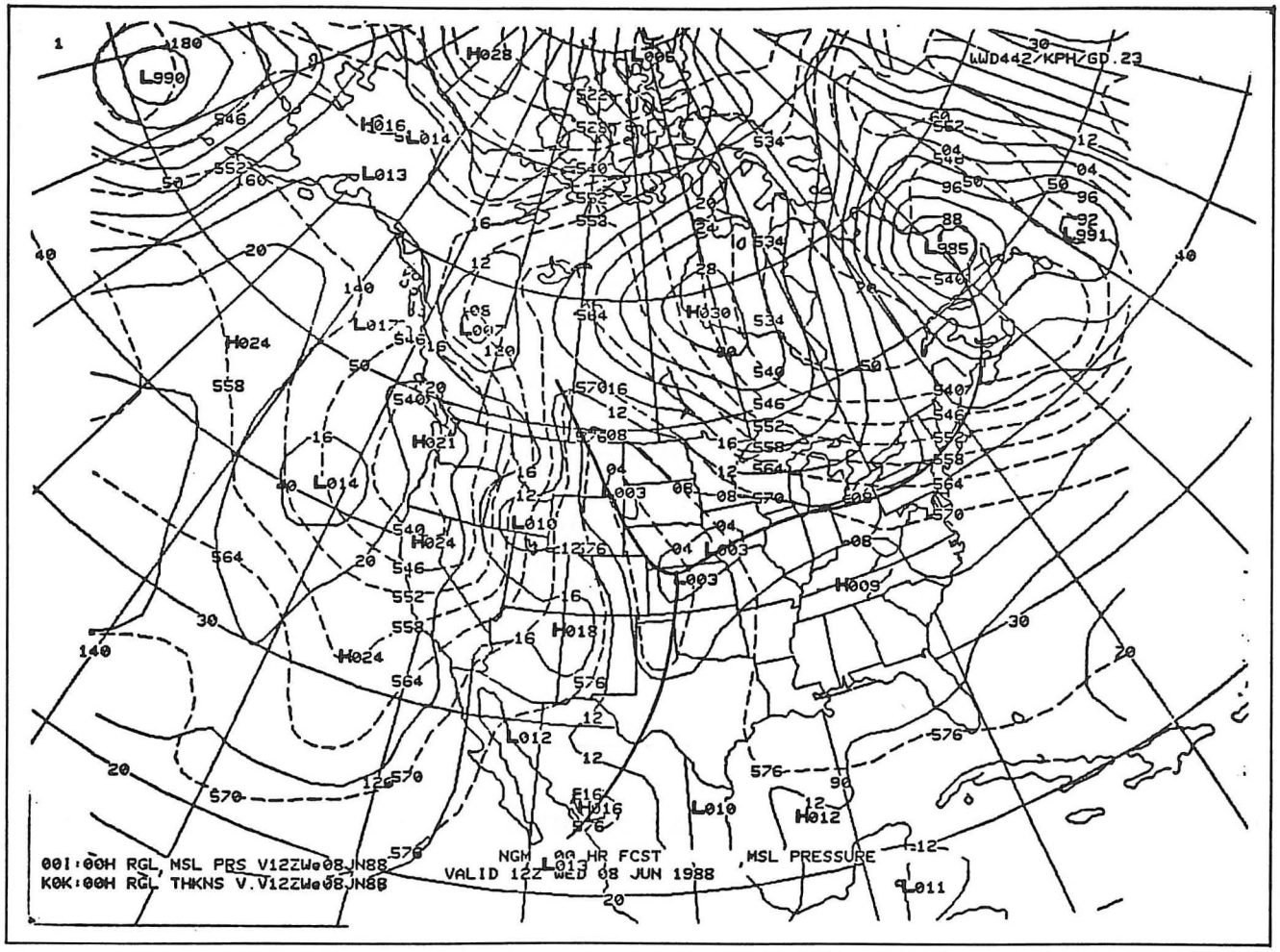

Fig. 12. Surface chart 1200 GMT June 8, 1988.

Solid lines—isobars; dashed lines—thickness

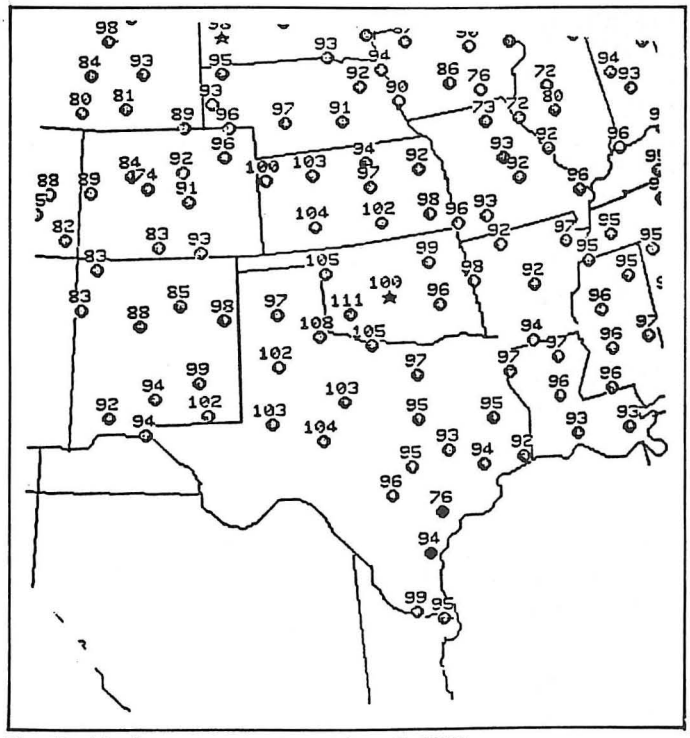

Fig. 13. Maximum temperatures June 8, 1988.

8. CONCLUSION

The heat-wave of 1980 and subsequent heat-waves encourage the development of forecasting tools to aid in predicting the magnitude and duration of intense heat. Forecasting tools may increase in importance if long-term atmospheric warming by air pollutants (greenhouse effect) is confirmed.

Accurate forecasting of intense heat will continue to be of concern because of the effects heat-waves have on the health and well being of individuals, and the price paid by society in utility and agricultural costs.

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