PREDICTING SEVERE AGRICULTURAL FREEZES

Edward A. Brotak (1)
Atmospheric Sciences Program
UNC Asheville
Asheville, NC 28804

ABSTRACT

A synoptic climatology of severe freezes in the year 'round agricultural areas of the United States was performed to determine if characteristic situations occurred. Such freezes were associated with major surface anticyclones of polar or arctic origin. These "super Highs" developed under high-latitude, upper-level ridges whose eastern side had a pronounced southwest to northeast tilt. This tilt is believed to be at least partially responsible for the abnormal development and trajectory of the surface High.

1. INTRODUCTION

"Hard Freeze Hits Citrus Crops in Florida!" Such headlines have become common in recent years (2,3,4,5,6,). Similar events have recently occurred in the other year 'round agricultural areas of the United States (7,8). These three agricultural areas, central and southern Florida, southern Texas, and southern California and southwest Arizona (see Fig. 1), account for not only most of the citrus supply in the United States but also a good portion of the vegetable production, especially in the winter. These crops are extremely susceptible to frost and freeze damage. Because of this, these crops are limited to areas where frosts are unusual and normally not severe (see Fig. 2). Certainly, temperatures well below freezing can be catastrophic.

During some freeze situations, various protection methods have value. Certainly, accurate forecasts of critical weather conditions are beneficial in protection strategies. The NWS has been very successful in forecasting frosts and freezes in the short term (24 to 36 hr). Occasionally, longer range warnings have been issued. It would be extremely useful in terms of forecasting if the synoptic situations which produced severe freezes could be identified well ahead of the freeze event. To achieve this goal, a synoptic climatology of major agricultural freezes has been undertaken. Hopefully, since these are still relatively rare events, the characteristic synoptic situation is fairly unique and easily recognizable.

2. DATA

The dates and locations of major freezes, those which produced millions of dollars of damage, were obtained through the sources listed in Table 1. The synoptic situation for each occurrence was determined by examining the surface and, when available, the 500-mb charts utilizing the Historic Weather Map Series and the Daily Weather Maps.

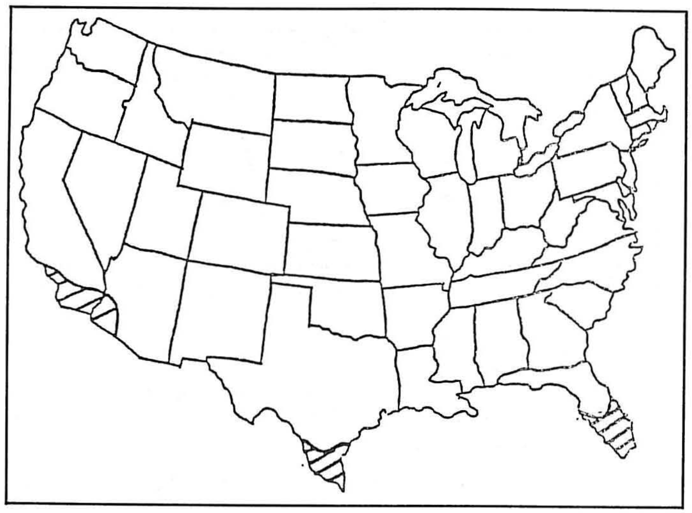

Fig. 1 Three major year 'round agricultural areas in the United States.

Table 1. Date and location of major freezes and maximum surface pressure of associated Highs

Date	Location	Max. Sfc. Pres.
1. 2/13/99	Texas (10)	1059 mb
2. 1/22–24/30	Texas (10)	1055 mb
3. 1/29–31/49	Texas (10)	1047 mb
4. 1/29–2/3/51	Texas (10)	1060 mb
5. 1/12/62	Texas (10)	1060 mb
6. 3/5/65	Texas (10)	1032 mb
7. 12/21/68	California (7)	1048 mb
8. 12/6–9/78	California & Arizona (7)	1045 mb
9. 1/3/79	Texas (8)	1052 mb
10. 3/2–4/80	Florida (2)	1049 mb
11. 1/12–14/81	Florida (2)	1045 mb
12. 1/10/82	Florida (3)	1055 mb
13. 12/25–26/83	Florida (4,5)	1061 mb
14. 1/21–22/85	Florida (6)	1048 mb

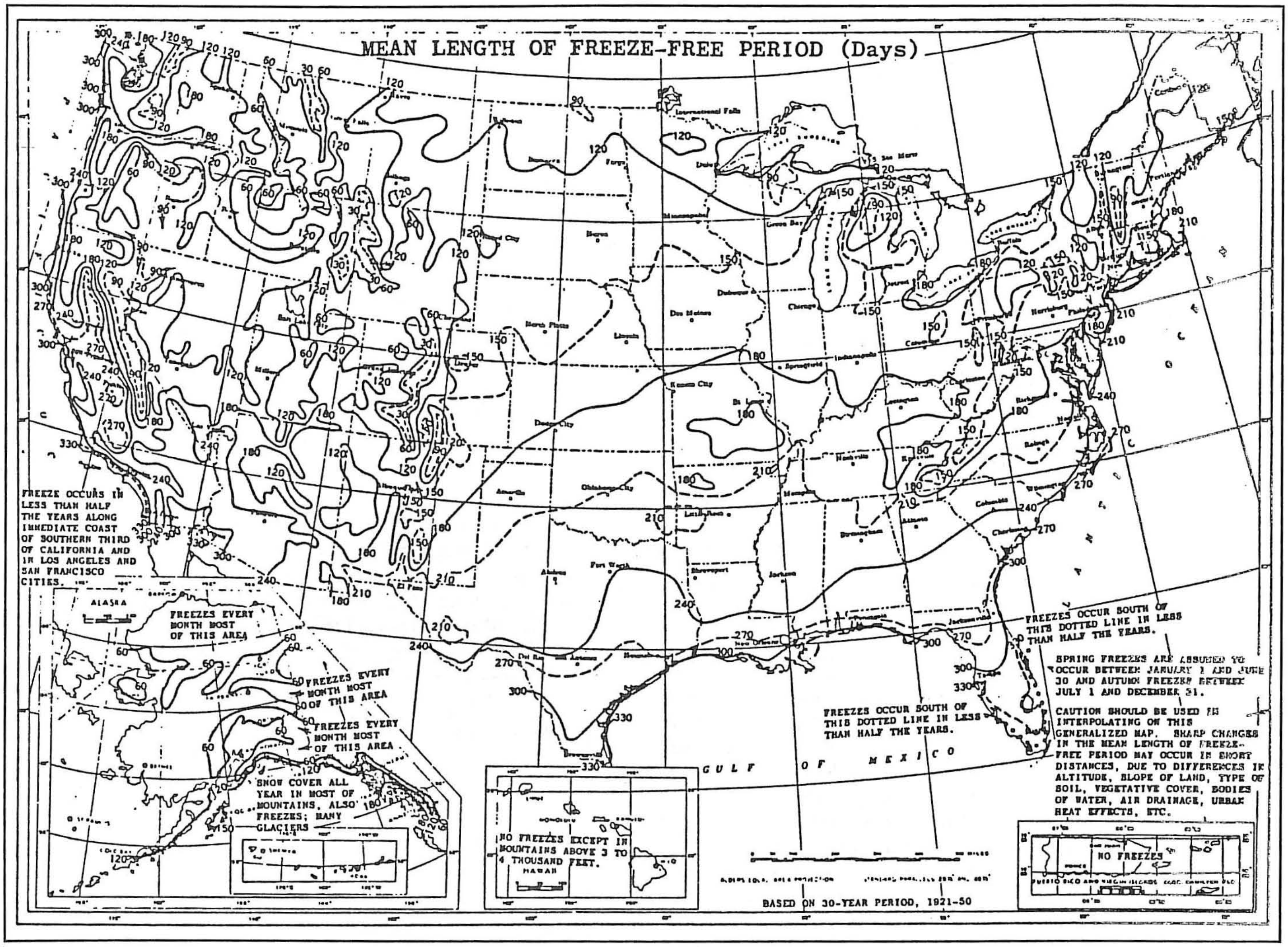

Fig. 2. Growing season in the United States.

3. RESULTS

As one would suppose, major freeze events occurred when the area was under the influence of a high-pressure system of polar or arctic origin. The extremely low temperatures were the result of strong cold advection as well as radiational cooling at night. The importance of advection cannot be minimized, since freezing temperatures with some wind foil those protection efforts that are usually successful under radiational conditions.As shown in Table 1, the intensity of these influencing anticyclones is extreme. Only in one case was the maximum central pressure of the High less than 1040 mb. This leaves two major questions: how are such strong Highs produced and why did they move so far south?

Pressure systems at the surface can be produced in two ways, thermally and dynamically. Cold air, being dense, weighs more and would produce higher pressures at the surface. Certainly, the air masses involved in these freeze events are extremely cold and have a strong thermal component to their pressure distribution. However, cold air alone cannot explain the extremely high pressures, as even colder temperatures are often observed in higher latitudes with lower surface pressures. Clearly, the dynamic component is very important.

Rising pressures at the surface can be produced by accumulation of air aloft, i.e., convergence. Convergence can be produced by decreasing wind speeds downstream, i.e., speed convergence, or by confluence in the flow. Confluence is classically found on the eastern side of upper-level ridges (9). Surface Highs usually develop underneath these areas of convergence aloft. An examination of the 500-mb situations did indeed show that the surface Highs in this study were produced under the east side of an upper-level ridge centered in Alaska or western Canada. Of interest was the orientation of those ridges which were not perpendicular. The eastern side of all of the 500-mb ridges in question had a pronounced tilt from northeast to southwest (Fig. 3). It is believed that such a configuration produces maximum confluence aloft and thus abnormally strong surface highs. It is analogous to a negative-tilt trough (northwest to southeast) that produces extreme cyclogenesis. A negative-tilt trough is often part of the evolutionary process when a closed Low is generated from an open-wave trough. In the freeze situations, often a closed High aloft developed. As McFarland (10) noted, an

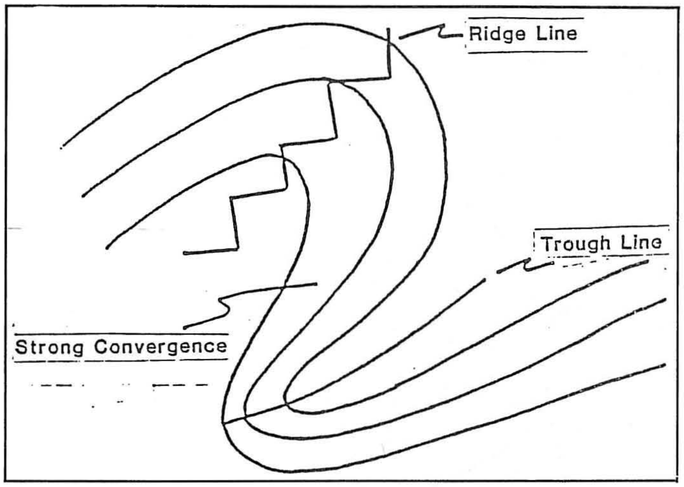

Fig. 3. A characteristic 500-mb pattern for extreme anticyclogenesis.

omega block in Alaska preceeded severe freeze situations in Texas by several days. In summary, strong confluence aloft produced by this unusual pattern, in association with cold air found at these high latitudes, produced the abnormally strong surface Highs.

The remaining question is: why did the Highs move so far south? McFarland noted that, although the omega block pattern preceeded the freeze situation in Texas, it was not until after the block broke down that the freeze occurred. The current study indicates that, although the surface High develops under the tilted ridge, it is not until the positive-tilt trough on the east side of the ridge starts to move south and east that the surface High leaves its area of origin. The trough releases and the surface High follows it south and east. Once the trough starts to move, we now have a steering current for the surface High. As the trough rotates to a more perpendicular orientation, the steering current is due south. Surface Highs also tend to propogate towards warmer air aloft (9). Thus, these surface Highs will be deflected somewhat west-

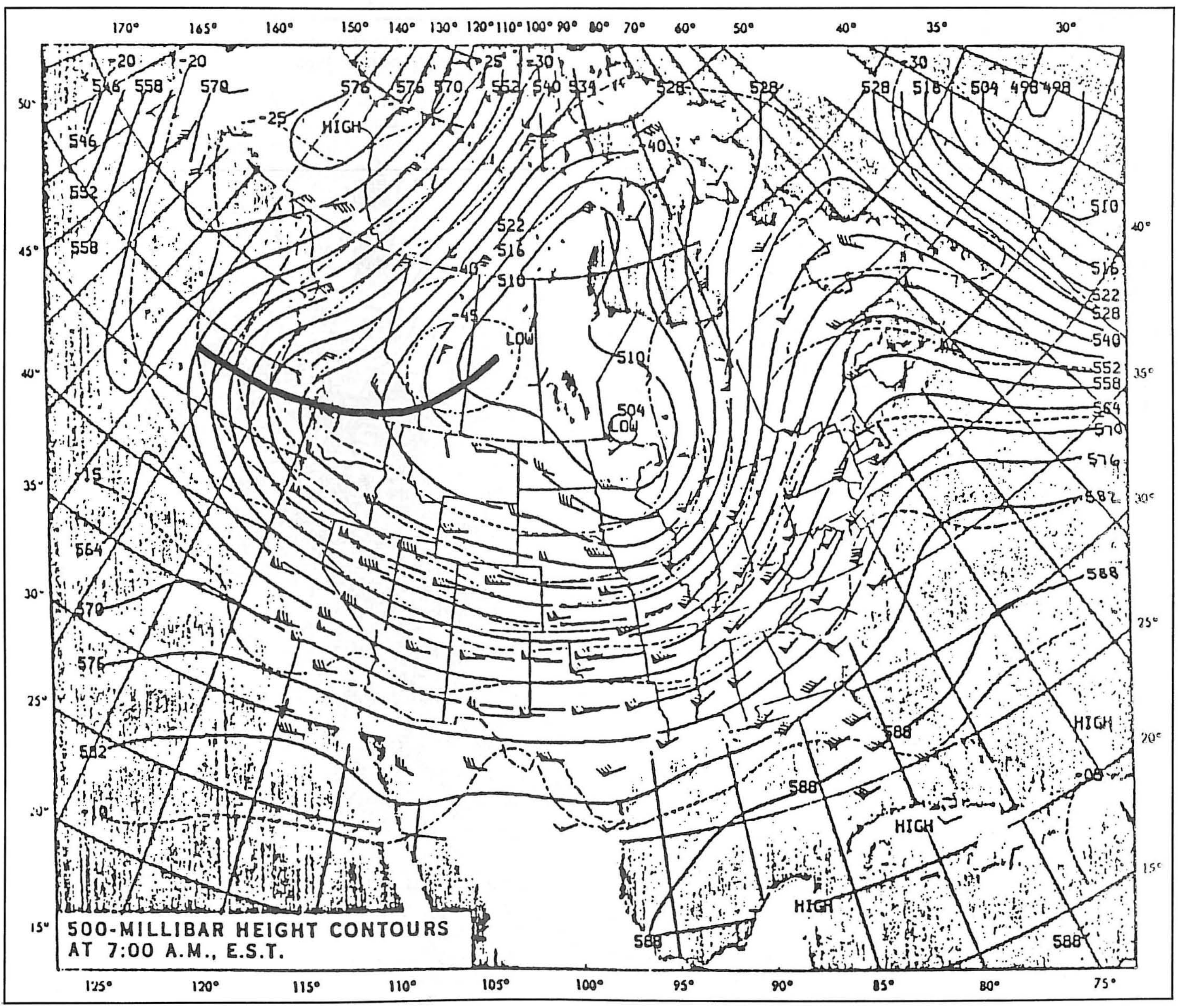

Fig. 4. The 500-mb chart for 1200 GMT December 22, 1983.

ward of the steering current aiding their penetration into low latitudes. The extreme intensity and coldness of the air mass allows it to penetrate much further equatorward than normal despite vertical shrinking and low-level moderation.

4. CASE STUDY

The Christmas freeze of 1983 represents one of the great Arctic outbreaks in history. Agricultural losses were staggering. Damage in southern Texas was estimated in the hundreds of millions of dollars. Even harder hit was Florida. Citrus losses alone exceeded $1 billion. Lowest temperatures in Florida included 11°F at Jacksonville, 19°F at Tampa, 20°F at Orlando, 30°F at West Palm Beach, and 33°F at Miami (5). Although being an extreme case, this situation did illustrate the basic pattern common to other freeze events.

Figure 4 illustrates the 500-mb pattern several days before the outbreak. In this extreme event, the Polar Vortex was involved. A major ridge with a closed High was over the Yukon. The trough in question was really a spoke rotating around the Polar Vortex. Note that at this time the trough orientation was extreme, almost east-west. This allowed the development of the major surface High behind the upper trough. Figure 5 shows how the trough rotated southward

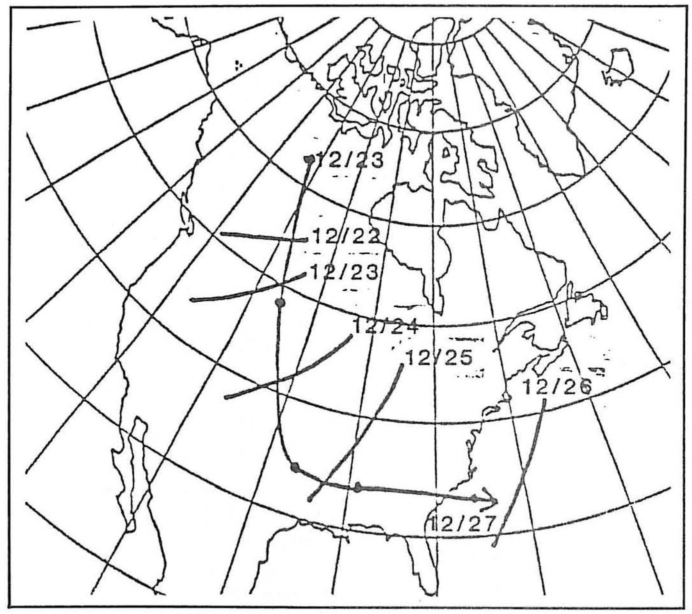

Fig. 5. Tracks of the 500-mb trough (solid line) and surface High (arrow) for the December 1983 Freeze.

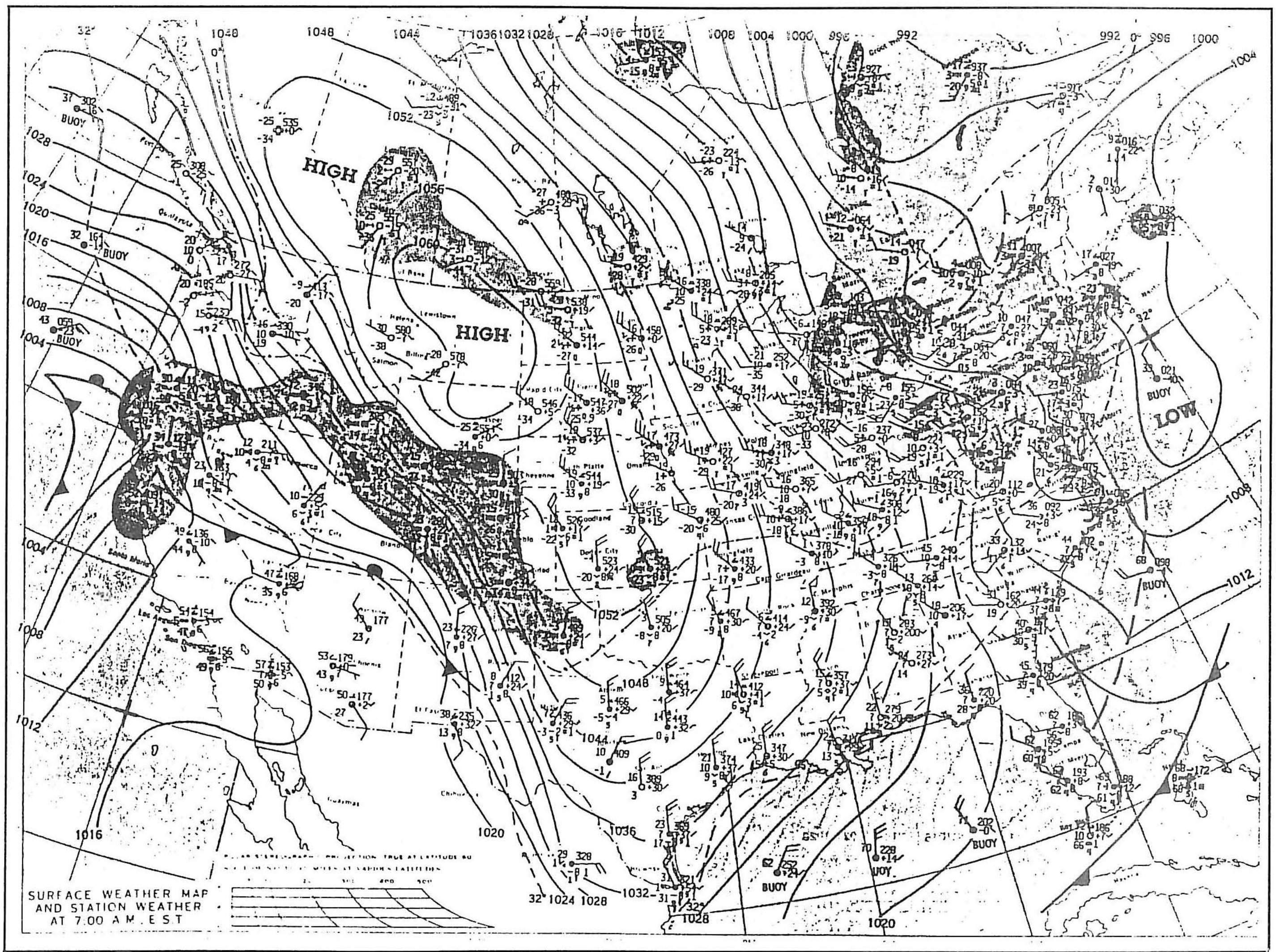

Fig. 6. Surface chart for 1200 GMT December 24, 1983.

and eastward over the four days. Also shown is the track of the surface High, which dropped almost straight south into the lower latitudes. Figure 6 shows the extreme surface High on the morning of the 24th. Central pressure is near 1060 mb.

5. SUMMARY

This study indicates that there are recognizable patterns prior to the occurrence of severe freezes in the year 'round agricultural areas of the United States. Extreme surface anticyclones are produced under regions of strong confluence aloft in Alaska and northwestern Canada. This confluence is produced by a northeast-to-southwest tilted upper ridge which may develop into a closed High over Alaska. The resulting surface High will follow the positively tilted trough as it moves south and east. This characteristic pattern can be recognized at least several days before the cold air mass reaches critical areas. Topics for future research would include the occurence of such extreme high-pressure areas which did not produce severe freezes (a false alarm ratio) and the dynamics behind these major Arctic outbreaks.

NOTES AND REFERENCES

1. *Edward A. Brotak received his B.S. and M.S. in meteorology from Rutgers University and his Ph.D. in biometeorology from Yale University. He is currently an Associate Professor in the Atmospheric Sciences Program at UNC Asheville. His research interests include synoptic meteorology, weather forecasting, forest meteorology, and agricultural meteorology. He is also the Meteorology Education Editor for the Digest.*

2. *Haddock, D., 1981: Florida's Severe Freeze Affects Citrus: January 12–14, 1981.* Weekly Wea. and Crop Bull., *68(5), 11–4.*

3. *Haddock, D., 1982: Siberian Express Brings Severe Freeze to Florida's Citrus and Vegetables: January 10–12, 1982.* Weekly Wea. and Crop Bull., *69(4), 7–10.*

4. *Brandii, H.W., 1984: December Florida Freeze of 1983.* Nat. Wea. Dig., *9(2), 36.*

5. *Mogil, H.M., A. Stern, and R. Hagen, 1984: The Great Freeze of '83—Analyzing the Causes and Effects.* Weatherwise, *37(6), 304–308.*

6. *----, 1985: Severe Freeze of Florida's Citrus and Vegetables, January 21–22, 1985.* Weekly Wea. and Crop Bull., *72(4), 2.*

7. *Haddock, D., and R. Hamilton, 1978: Major Freeze—California and Arizona in December 1978.* Weekly Wea. and Crop Bull., *65(52), 9–11.*

8. *Haddock, D., and C. Connolly, 1979: Major Freeze—Lower Rio Grande Valley of Texas, January 2–3, 1979.* Weekly Wea. and Crop Bull., *66(3), 10–13.*

9. *Palmen, E., and C.W. Newton, 1969:* Atmospheric Circulation Systems, *603 pp.*

10. *McFarland, M.J., 1979: Long Range Forecasting of Major Freeze Events in the Lower Rio Grande Valley.* Proceedings of the 14th Conference on Agricultural and Forest Meteorology, *Minneapolis, MN 2–6 April 1979, 1–4.*