**Western Region Technical Attachment**
**No. 94-30**
**September 27, 1994**

# AGRICULTURAL HARD-FREEZE EVENTS IN THE GREATER PHOENIX AREA: SOME ASSOCIATED MEAN ATMOSPHERIC PATTERNS

**Jesus A. Haro - WSFO Reno**

## Introduction

Recently, National Meteorological Center (NMC) grid point data were received by Western Region Professional Development Workstation (PDW) sites via CD-ROM. Included with the CD-ROM were data retrieval, compositing, and graphical display software that allows the user to manipulate and display historical NMC grid point Northern Hemispheric analyses and composites. Thus, forecasters at these sites have been given a powerful and versatile tool for meteorological research.

The versatility of this package proved valuable in a recent study that identified mean atmospheric patterns associated with weather phenomena in North Dakota (Fors and Leblang 1993). The purpose of this Technical Attachment is to briefly summarize the results of a similar study done for agricultural hard-freeze events in the greater Phoenix area.

## Background

Prominent among the myriad of economic forces in the greater Phoenix area is the agricultural community. Accordingly, the Phoenix NWSFO has been diligent in its pursuit to provide valuable and reliable agricultural forecasts to growers in this area during the frost season (November 15 - March 15). The ability to forecast crop-damaging hard-freeze events is extremely important.

During the 1970s, agricultural hard-freeze events were based on minimum temperatures at Phoenix's Sky Harbor Airport. In the early 1970s, an agricultural hard-freeze was said to have occurred if the minimum temperature at the airport dropped to ≤ 32°F for at least three hours. Rapid urbanization during the 1970s in and around Sky Harbor Airport required that the definition be modified. Thus, during the middle and late 1970s, the minimum temperature threshold was increased to 35°F. Continued rapid urbanization in the area required yet another modified definition.

Currently, agricultural hard-freeze events in the greater Phoenix area are operationally defined as those in which at least four of the key agricultural stations report temperatures of ≤ 28°F, for at least five hours, during a 24-hour period (Craig Ellis, personal communication). This period of time is critical for the protection of citrus crops since they may be damaged or ruined when temperatures meet these criteria.

Accurately forecasting these events is difficult since agricultural hard-freeze events are relatively rare in the greater Phoenix area. On average, only about three agricultural hard-freeze events occurred per year between 1969 and 1989, the time domain of this study.

## Methodology

The NMC Grid Point Data Set was used to identify variables that had a consistent relationship with agricultural hard-freeze events. Among the archived data set variables, 500 mb height and 700 mb temperature appeared to have the most operational utility for the forecasting of these events. These variables are good indicators of the characteristics of a critically cold airmass associated with each wintertime weather system.

Annual Fruit Frost program summaries for the period 1969-1989 were used to identify the occurrence of agricultural hard-freeze events in the greater Phoenix area. Dates in which the current agricultural hard-freeze criteria were met were logged and included in this study.

## Results

Sixty-two agricultural hard-freeze events occurred from 1969 through 1989. All but seven of the events occurred during December and January. These events typically occurred as part of a cold outbreak lasting at least two days. Inspections of 500 mb height and 700 mb temperature analyses for the time periods prior to and after each agricultural hard-freeze event were made. Two main synoptic regimes appear to be associated with these events. Analyses corresponding to the times of the lowest 500 mb height and lowest 700 mb temperature over Phoenix for each outbreak or event were chosen to comprise the composites for each regime. The regimes causing these events were then separated into two types (Type A and B).

### I - Type A Pattern

Type A is characterized by the development of a vigorous, high-amplitude 500 mb trough over the Great Basin (Figs. 1a-e). Forty-eight hours prior to the time of the lowest height over Phoenix (Fig. 1a), a trough is evident over western Canada extending south into Washington and Oregon, with another very weak trough off the Baja California coast. Twenty-four hours later (Fig. 1b), the western Canadian trough deepens significantly over the Great Basin, merging with the Baja trough, as a 500 mb high pressure ridge builds impressively onto the western Canadian coast. At the time of the lowest 500 mb height over Phoenix (Fig. 1c), the trough deepens into Arizona as the offshore ridge moves over the West Coast of the United States and western Canada. The geopotential height over Phoenix falls to approximately 5430 meters. Twenty-four (Fig. 1d) and 48 (Fig. 1e) hours later, the trough fills and lifts northeastward as the high pressure ridge weakens and moves into the western United States.

Composite analyses of 700 mb temperatures (Figs. 2a-e) give an indication of the cold Type A airmass. Forty-eight (Fig. 2a) and 24 (Fig. 2b) hours prior to the time of the lowest 700 mb temperature over Phoenix, strong cold air advection took place across Arizona in response to the digging 500 mb trough. The coldest 700 mb temperature over Phoenix (Fig. 2c) is about -13°C. Twenty-four (Fig. 2d) and 48 (Fig. 2e) hours later, some temperature recovery is evident with temperatures rising to about -7°C and -3°C, respectively.

II - Type B Pattern

The Type B pattern is similar to type A with the development of a vigorous, high amplitude 500 mb trough over the Great Basin (Figs. 3a-e). The development of a secondary trough over the Pacific Northwest is the main feature distinguishing Type B from Type A. Forty-eight hours prior to the time of the lowest height over Phoenix (Fig. 3a), a developing trough can be seen over the Pacific Northwest coast. Twenty-four hours later (Fig. 3b), the trough deepens over the Great Basin as the offshore ridge pushes into the west coast (though not as strongly as with Type A). At the time of the lowest height over Phoenix (Fig. 3c), the trough deepens over Arizona as the ridge moves east. The geopotential height over Phoenix falls to about 5450 meters. The West Coast ridge isn't so pronounced as with Type A. Twenty-four hours after the time of the lowest height over Phoenix (Fig. 3d), a secondary trough along the Pacific Northwest coast appears to eject the first trough into the Great Plains. Forty-eight hours after the time of the lowest height over Phoenix, the secondary trough has deepened over Arizona helping to carve out a broad area of low pressure over the western United States.

Composites of 700 mb temperatures (Figs. 4a-e) show that the Type B exhibits temperature characteristics similar to Type A. Forty-eight (Fig. 4a) and 24 (Fig. 4b) hours prior to the time of the lowest 700 mb temperature over Phoenix, strong cold air advection takes place across Arizona in response to the digging trough at 500 mb. The coldest 700 mb temperature over Phoenix (Fig. 4c) is about -13°C. The analyses for 24 (Fig. 4d) and 48 (Fig. 4e) hours after the time of the lowest 700 mb temperature over Phoenix outline the presence of the secondary trough. Temperatures over Phoenix do not recover as quickly as with Type A, remaining at around -7 or -8°C.

## Conclusions

This paper identifies large scale patterns associated with agricultural hard-freeze events in the greater Phoenix area. The importance of the strength and orientation of the offshore high pressure ridge during these events is evident. The ridge orientation and amplitude appear to play a major role in dictating which type will occur.

However, these composite analyses should not be used for prediction. The composites only represent the chosen cases for this type of event, and are a subset of all such matching patterns. In order to use these in a predictive sense, one must identify all patterns matching the composites and determine the number that are classified as freeze and non-freeze events. Only if a significant number of all these matching patterns correspond to freeze events can one conclude that any cases matching the composites will likely be freeze events. This was not done for this study.

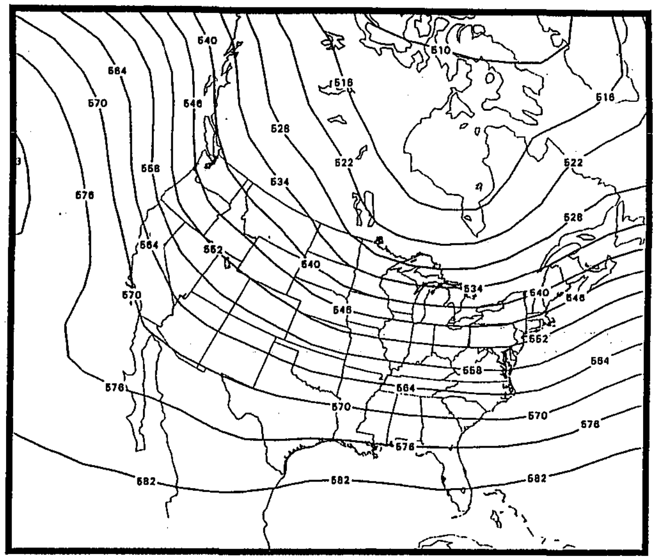
Although these results suggest that 500 mb heights and 700 mb temperatures must drop to certain levels over Phoenix before agricultural hard-freezes can occur in the Phoenix area, it must be stressed that in most cases a lag time of twelve to twenty-four hours existed between the time of lowest heights and temperatures over Phoenix at those levels and the occurrence of the first agricultural hard-freeze event in an outbreak (if the agricultural hard-freeze is assumed to be at its peak at 1200 UTC on any given day). The lag time was likely a function of the time it took to establish conditions favorable for maximum radiational cooling (clear skies, light winds, drying of the airmass in the lower levels): on one occasion, the lag time was approximately 60 hours. On a much more infrequent basis, the first agricultural hard-freeze event of an outbreak occurred concurrent with the time of lowest height and temperature over Phoenix at those two levels.

The forecaster should consult other variables and aides (MOS guidance, thickness values, etc.) and use sound meteorological judgment before being able to effectively use any of these composite maps as part of the forecast process for this type of event. The use of these composite analyses for prediction is very limited. However, these composites do provide a framework for the forecaster's benefit.

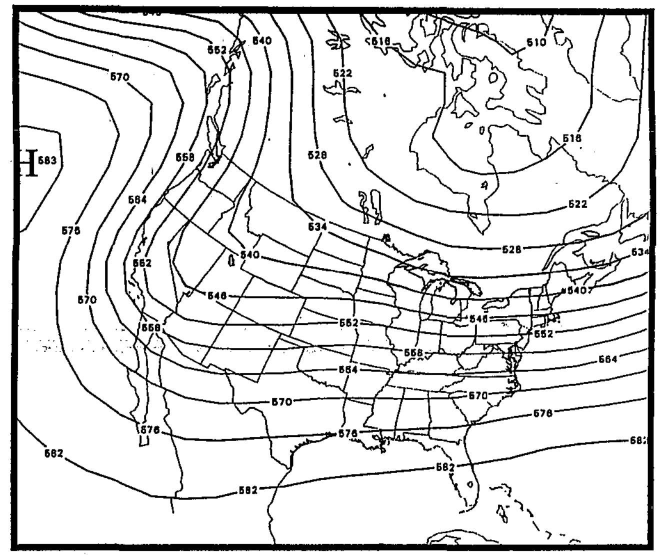
*Acknowledgments*: Compositing software was developed by Mark Albright at the University of Washington. Graphical display (NMCDRAW) and laser printing software were developed by Richard Leblang (WSFO Bismarck). Thanks to Craig Ellis, Mike Franjevic, Doug Green, Hector Vasquez (WSFO Phoenix), and Keith Meier (WRH SSD) for providing critical input that led to improvements in this paper.

**Reference**

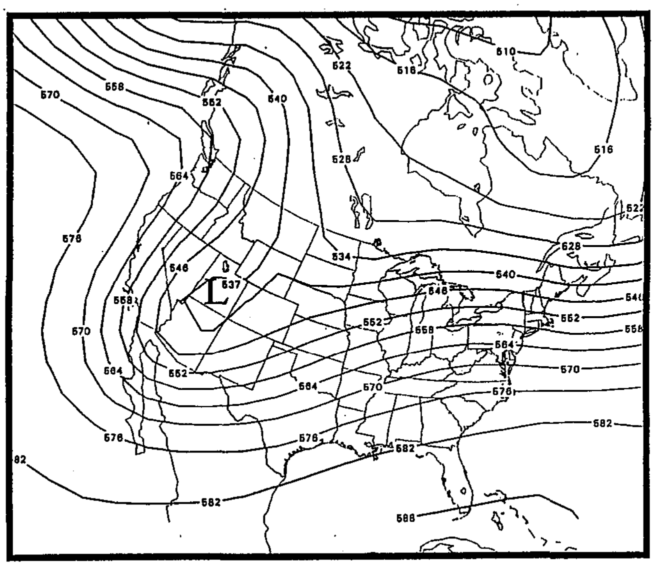
Fors, J.R. and R.S. Leblang, 1993: Mean Atmospheric Patterns Associated with Heavy Rain and Freezing Rain at Bismarck, North Dakota: An Initial Study Using Historical NMC Data on CD-ROM. *National Weather Digest*, **18**, 32-37.



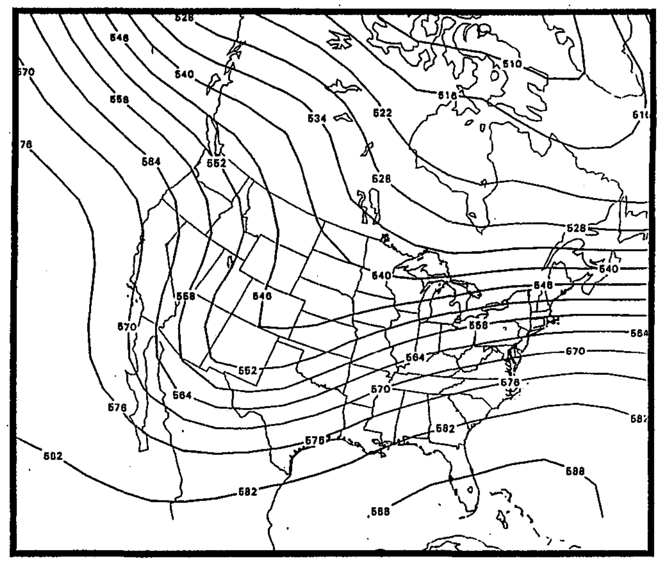
a



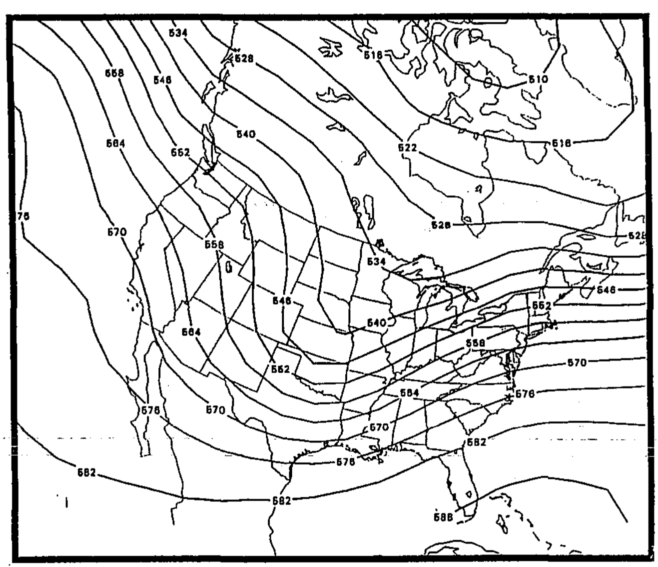
b



c

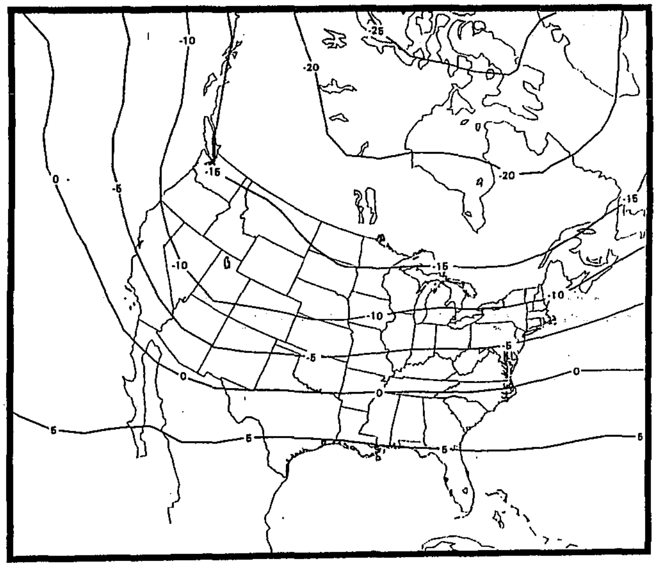


d

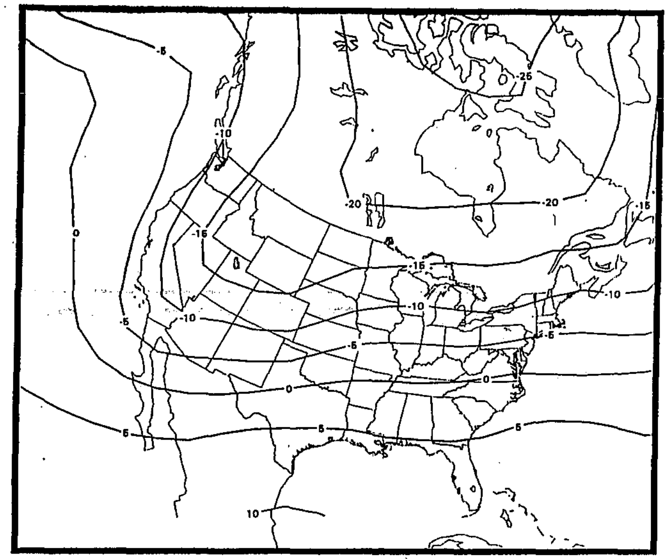


e

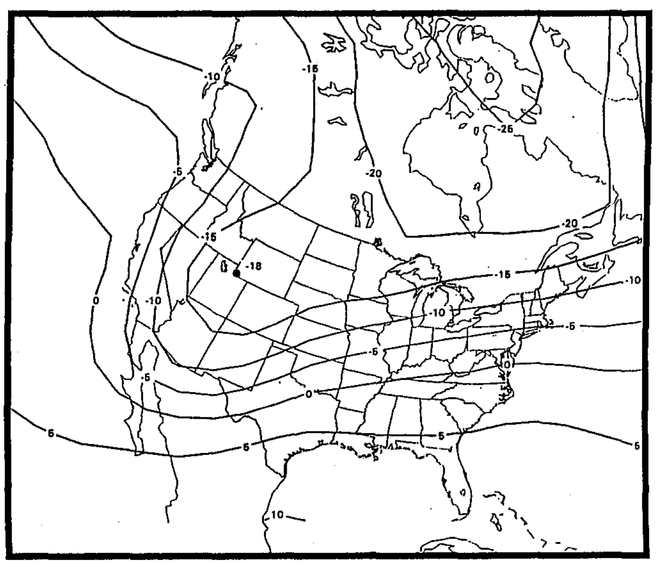
**Fig. 1** Type A 500 mb composite analyses for a) 48 and b) 24 hours prior to c) the time of lowest height over Phoenix, and d) 24 and e) 48 hours after.



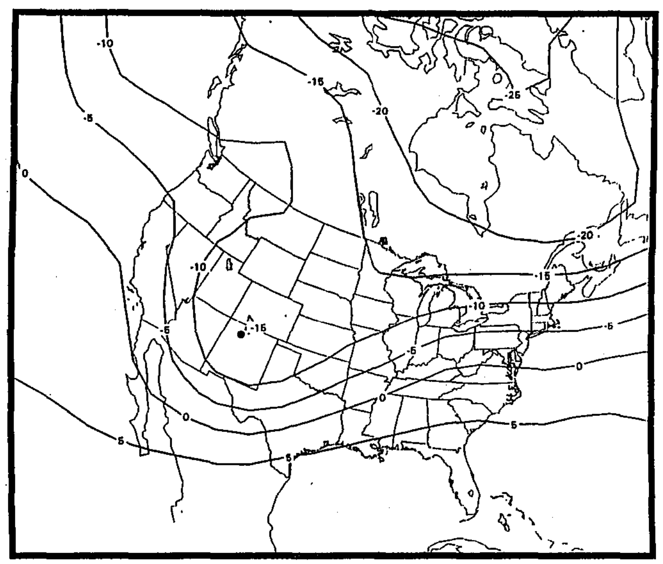
a



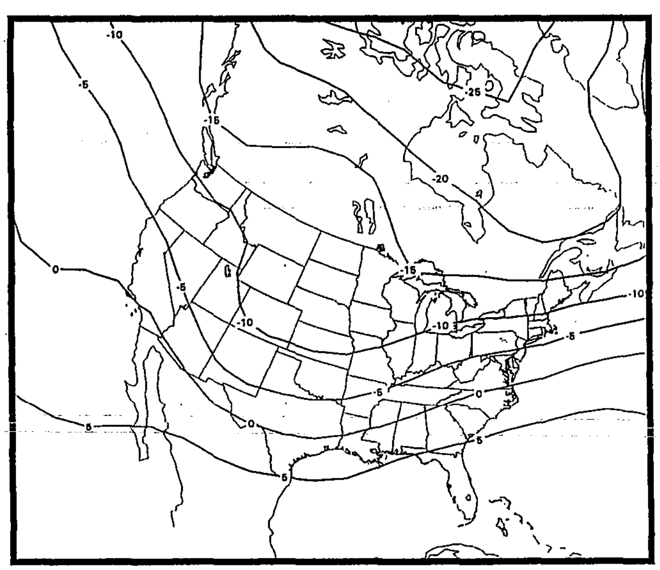
b



c

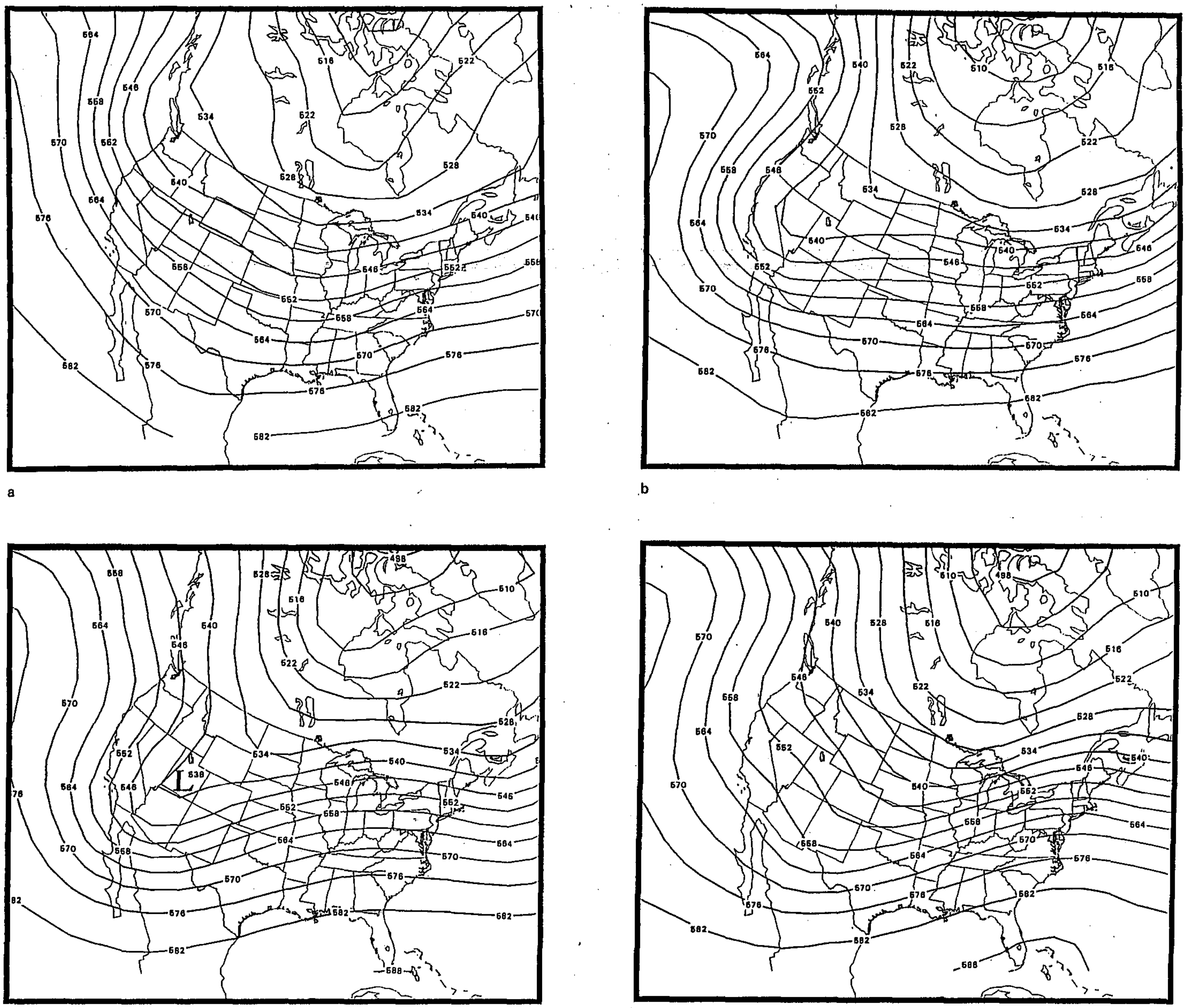


d



e

**Fig. 2** Type A 700 mb temperature analyses for a) 48 and b) 24 hours prior to c) the time of the lowest 700 mb temperature over Phoenix, and d) 24 and e) 48 hours after.

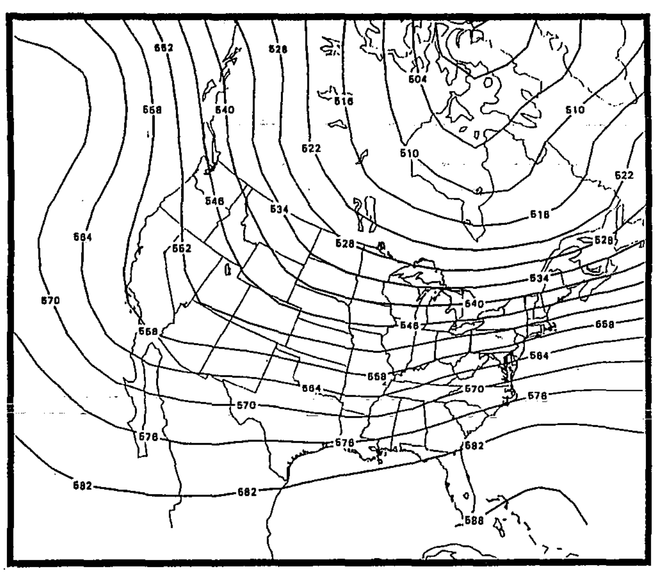


a

b

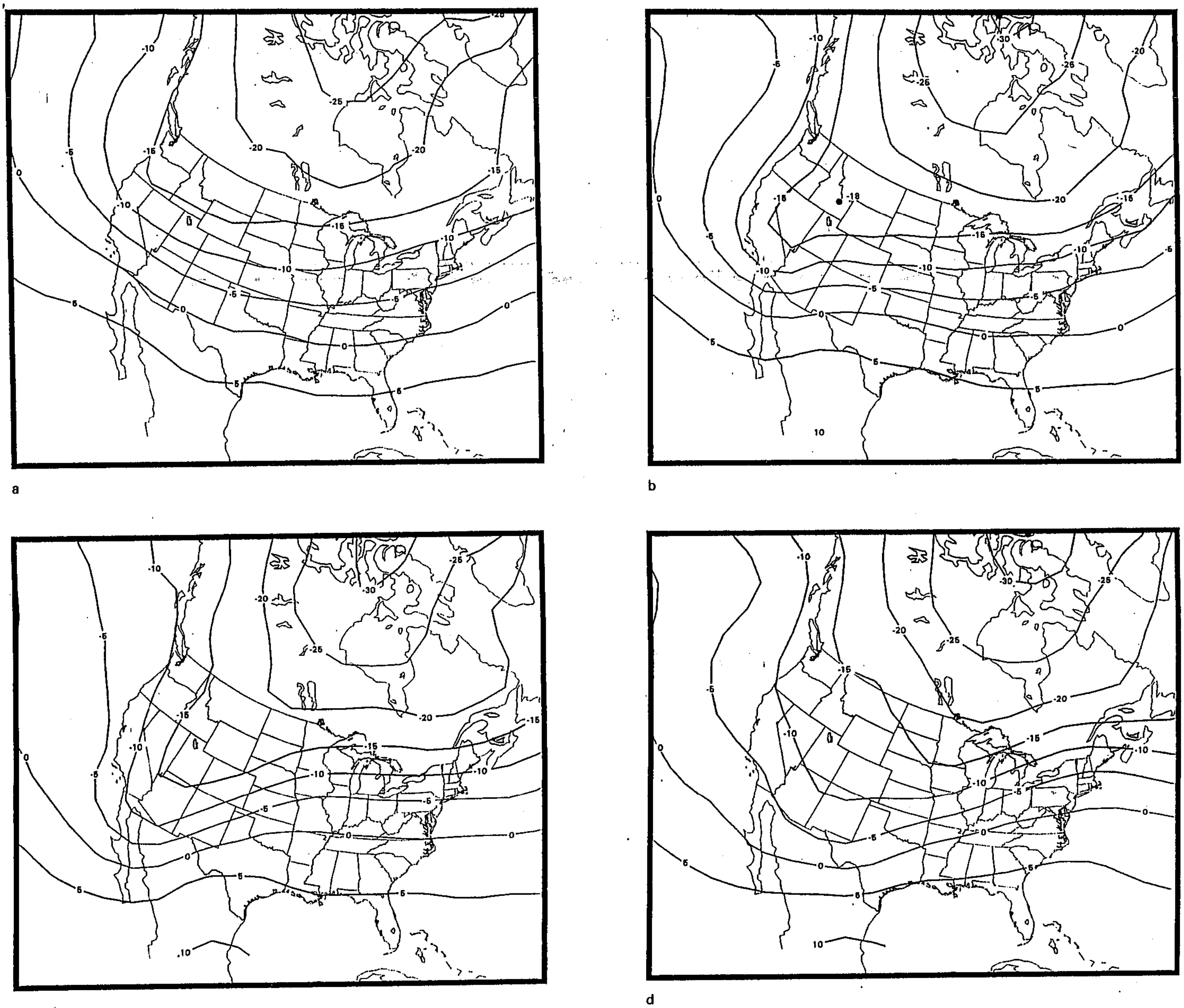
c

d



e

**Fig. 3** Type B 500 mb composite analyses for a) 48 and b) 24 hours prior to c) the time of lowest height over Phoenix, and d) 24 and e) 48 hours after.



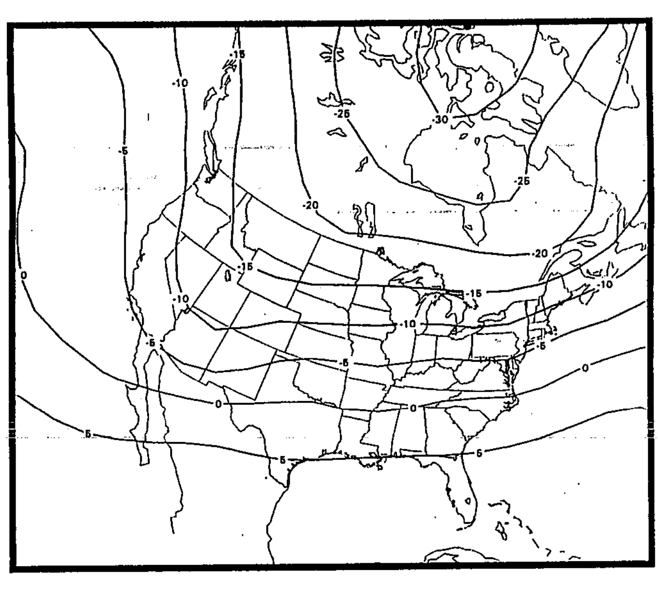


**Fig. 4** Type B 700 mb temperature analyses for a) 48 and b) 24 hours prior to c) the time of the lowest 700 mb temperature over Phoenix, and d) 24 and e) 48 hours after.