

# Forecast

## INVESTIGATION OF HEAVY SNOW SITUATIONS AT ALBUQUERQUE, NEW MEXICO

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### ABSTRACT

*Utilizing data from 1950 through 1977, synoptic models are presented for heavy snow situations at Albuquerque, New Mexico. The preferred location of the upper-level lows or troughs is found to be in a 500 kilometer square just to the west of Albuquerque. The heavy snow appears to be related to strong positive vorticity advection in the middle and upper troposphere associated with the cyclonic curvature and horizontal wind shear. The middle and low levels are characterized by light winds which minimize downslope conditions. The required surface pattern is a high pressure ridge over western Texas and a trough near or just to the west of Albuquerque. This combination enhances the advection of low-level moisture and creates low-level convergence.*

### 1. INTRODUCTION

Heavy snow is not a common occurrence in Albuquerque, New Mexico. During the period January 1950 through March 1977, heavy snow (equal to or greater than 10 cm/12 h or 15 cm/24 h) has fallen at the Albuquerque International Airport 11 times. Although surrounding higher elevations can receive heavy snow several times a year, this phenomenon is not routinely experienced in the lower elevations of the Rio Grande River Valley. During the 28 years, qualifying rain (equal to or greater than 1 cm/12 h or 1.5 cm/24 h) has occurred only 6 times with 3 of the cases associated with showers in March.

Since the population of Albuquerque is accustomed to generally dry weather, the associated problems of heavy snow can be acute. Precipitation amounts at the airport (just southeast of the center of town) are generally lower than in other sections of the city, especially the northeast.

Because of the size and geographical location of Albuquerque, much of the economic and aviation activities of New Mexico are centered in the city. Over 30 percent of the state's people reside in the Albuquerque metropolitan area, and a large percentage around the state frequently travel to the city. Adverse weather in Albuquerque can affect, either directly or indirectly, much of the population of New Mexico. Three-dimensional synoptic models would alert the forecaster to possible heavy snow situations at Albuquerque and the adjacent Rio Grande Valley.

### 2. DATA SOURCES AND PROCEDURE

Data for this study consisted of: Daily Series Synoptic Weather Maps, Daily Weather Maps Weekly Series and facsimile charts retained by the National Weather Service Forecast Office in Albuquerque. The former two

series of maps covered the period January 1950 through December 1972 and consisted of daily 500 mb and surface charts (observation times 1500 GMT or 1200 GMT). Since January 1973, facsimile charts have been routinely saved by the Weather Service Forecast Office. Among the various charts retained have been the 0000 GMT and 1200 GMT surface, moisture, radar composite, upper air and vorticity analyses as well as pseudo-adiabatic diagrams for Albuquerque and selected stations. Hourly surface observations for Albuquerque were also available.

Although 23 years of the study (1950-1972) were represented by only limited data, only 6 of the 11 heavy snow cases occurred during this time. Five of the incidents occurred during January 1973 through March 1977--the period with extensive information.

For the period 1950 through 1972, tracks of upper-level low centers, surface troughs and ridges as well as surface pressure centers could be extrapolated with some degree of confidence. Information on pressure and height patterns, which are somewhat less conservative, was more readily available from the January 1973 through March 1977 data.

Relating average pressure or wind patterns to

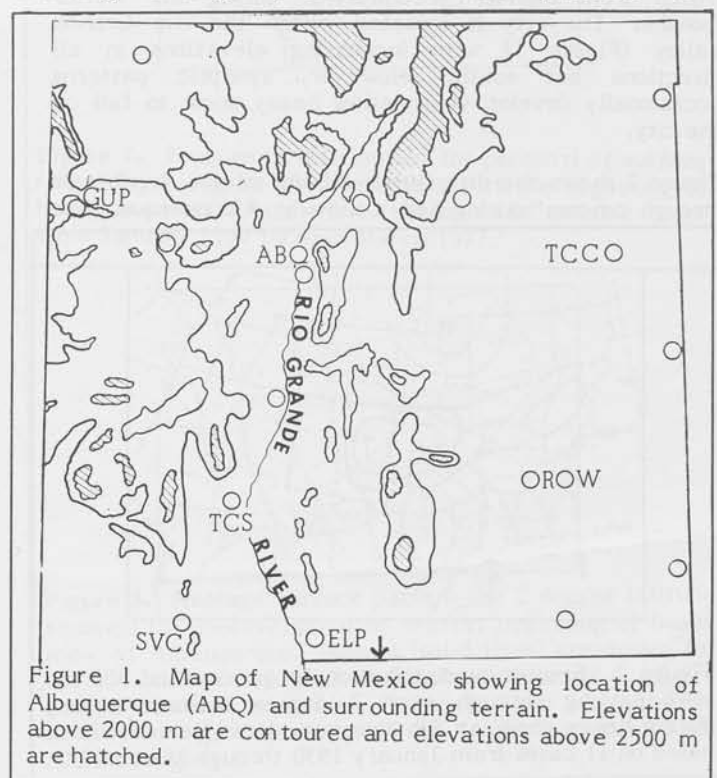


Figure 1. Map of New Mexico showing location of Albuquerque (ABQ) and surrounding terrain. Elevations above 2000 m are contoured and elevations above 2500 m are hatched.

meteorological phenomena can be misleading, especially if the composite represents varying patterns. However, because of the synoptic homogeneity of the cases in this study, certain aspects were amplified. Synoptic climatological models for heavy snow at Albuquerque were established from the averaged charts. The individual cases were compared to these models to reveal exceptions and subtle factors.

### 3. RESULTS

The importance of upper-air troughs and low pressure centers to winter precipitation in the mountainous Southwest has long been recognized. Jorgensen, Klein and Korte (2) derived a synoptic climatology of precipitation related to 700 mb closed lows for the intermountain area of the West for the months of December, January and February. The examination was later expanded to include low centers at 850, 700, 500 and 300 mb (3). Jorgensen, Korte and Bunce (4) examined the precipitation for individual stations in the Plateau Region resulting from 700 mb lows, and Augulis (5) determined the frequency of precipitation occurrence associated with winter 500 mb map types for selected stations in the western and southwestern United States. Williams and Peck (6) analyzed precipitation in northwest Utah with regard to "cold lows" and "non-cold lows" aloft and Vore and McCarter (7) briefly discussed upper-level cutoff lows that plunge into the Nevada area from the northwest during the fall months. Weather extremes over the southwestern United States associated with the development of a large-amplitude 500 mb trough was investigated by Saylor and Caporaso (8). Brown and Brintzenhofe (9) related the heavy snowfall in eastern New Mexico and northwestern Texas during the period 1 February through 5 February 1956 to the flow pattern and movement of the low aloft.

Surrounding higher terrain usually shields Albuquerque (ABQ) from heavier precipitation during the winter months. The city is situated within the Rio Grande Valley (Figure 1) with increasing elevations in all directions but south. However, synoptic patterns occasionally develop which allow heavy snow to fall on the city.

Figure 2 shows the distribution of 500 mb low centers or "trough centers" during heavy snow at Albuquerque. For

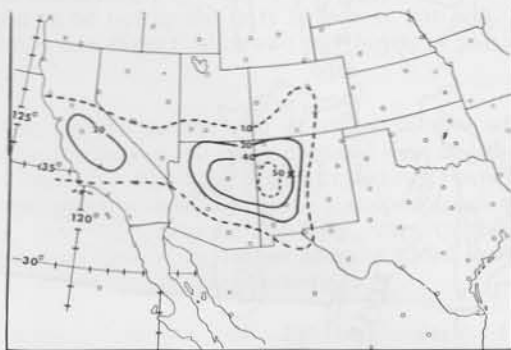


Figure 2. Frequency distribution (in percent) of 500 mb lows passing through each 2 degree latitude square during heavy snow at Albuquerque, New Mexico. Data based on 11 cases from January 1950 through March 1977.

convenience, a "trough center" was arbitrarily defined as the position on the trough line 2 degrees latitude north of the implied vorticity center. Although errors can result from this definition, they would not be prohibitive.

Greatest frequencies occur in a 500 km square located over eastern Arizona and western New Mexico. Klein, Jorgensen and Korte (3) found that for the most intense lows, the area of maximum frequency of measurable precipitation occurrence was located in the southeast quadrant five degrees latitude from the low center. Figure 2 suggests that for Albuquerque, the 500 mb low must be closer and farther south.

A second maximum is located over central California. Examination of the individual cases revealed the latter to be associated with an uncommon precipitation producing pattern. The elimination of the situations which contain this pattern left a total of nine cases with four occurring from January 1973 through March 1977.

Based on the movement of the centers in all nine cases, the long-wave trough must be located near the Arizona-New Mexico border. The centers moved east to southeast over Arizona and changed to an east to northeasterly direction over western New Mexico. Most were intensifying and none weakened. The snow usually stopped as the 500 mb low neared the station.

Figure 3, which shows the average 500 mb pattern at the beginning of heavy snow, is in basic agreement with Figure 2. The average "trough center" is located over eastern Arizona with the trough line extending south into northwest Mexico. The isotherms and contours are not completely in phase with cold air advection to the rear of the trough. Albuquerque is in the region dominated by cyclonic shear and just downstream from the area of maximum cyclonic curvature. Flow along the contours would be from the southwest. Southwesterly 500 mb flow over Albuquerque appears to be more favorable to heavy snow than winds with a more westerly component. An increased southerly direction favors moisture advection and is less normal to mountain ranges.

The average 700 mb chart (Figure 4) closely resembles the average 500 mb pattern. A broad trough is located along the Arizona-New Mexico border into northern Mexico. The thermal trough is displaced to the west

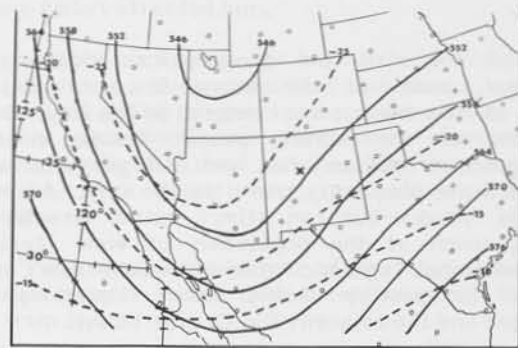


Figure 3. Average 500 mb chart (by 2 degree latitude squares) for observation time nearest beginning of heavy snow at Albuquerque. Contours (solid lines) are at 6 decimeter intervals and isotherms (dashed lines) at 5 degree intervals. Data based on four cases from January 1973 through March 1977.

about 450 km with cold air advection occurring to the rear of the height trough. Albuquerque is located within an area of weak height gradient with weak southwest geostrophic flow. The strongest height gradient lies to the south and southeast of the station. The location of the trough would agree closely with the optimum region for heavy precipitation suggested by Klein (10).

At 300 mb, the maximum winds are located over the Big Bend area of Texas (Figure 5) with speeds of over  $60 \text{ m s}^{-1}$ . In each of the heavy snow cases (four incidents), the maximum winds were within 200 km of the mean position. The location of the maximum winds at 300 mb would support movement of the upper-level trough to the east or northeast. Albuquerque is situated under an area

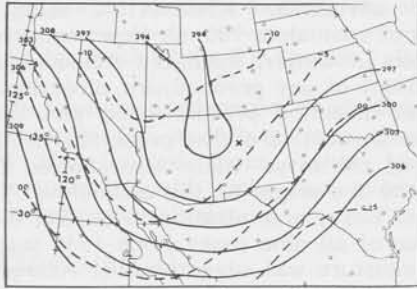


Figure 4. Average 700 mb chart (by 2 degree latitude squares) for observation time nearest beginning of heavy snow at Albuquerque. Contours (solid lines) are at 3 decimeter intervals and isotherms (dashed lines) at 5 degree intervals. Data based on four cases from January 1973 through March 1977.

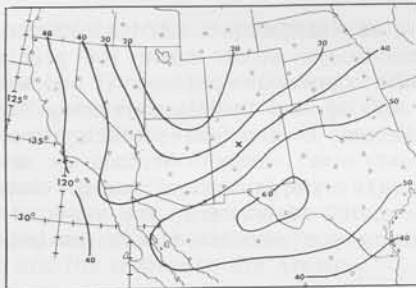


Figure 5. Average 300 mb wind speeds (by 2 degree latitude squares) for observation time nearest beginning of heavy snow at Albuquerque. Isotachs are at  $10 \text{ m s}^{-1}$  intervals. Data based on four cases from January 1973 through March 1977.

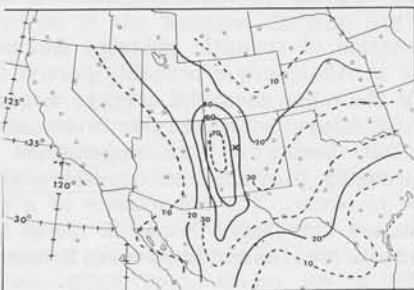


Figure 6. Frequency distribution (in percent) of surface troughs (by 2 degree latitude squares) at the beginning of heavy snow at Albuquerque. Data based on nine cases from January 1950 through March 1977.

of horizontal cyclonic shear. The station is also located under an area of apparent divergence associated with the maximum winds (11) and heavier precipitation (12).

Figure 6 depicts the distribution of surface troughs at the beginning of heavy snow at Albuquerque. For the purpose of this study, surface fronts were also included. A strong preference is shown for the western part of New Mexico. A second maximum extends from extreme western Texas into eastern Oklahoma.

The distribution of surface ridges shown in Figure 7 reveals highest frequencies over the Colorado-Kansas border and western Texas. The average pressure pattern (Figure 8) disagrees somewhat with Figures 6 and 7. A low pressure center is shown over the Big Bend part of Texas with a trough extending northwest through Albuquerque into southeast Utah. High pressure is indicated mainly in the Kansas and Colorado area northward. The disagreement could be the result of averaging. However, Figure 8 would be in relative close agreement with Younkin's (13) surface composite for the "digging" type.

The surface pattern in Figure 8 would also suggest a low-level southeast flow across western Texas into the eastern half of New Mexico. Strong warm air advection is indicated over these areas with weak cold air advection over southwest New Mexico. The warm air advection shown over eastern New Mexico and western Texas is not completely representative of the lowest



Figure 7. Frequency distribution (in percent) of surface ridges (by 2 degree latitude squares) at the beginning of heavy snow at Albuquerque. Data based on nine cases from January 1950 through March 1977.

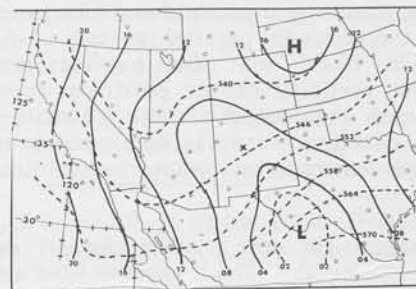


Figure 8. Average surface pattern (by 2 degree latitude squares) for observation time nearest beginning of heavy snow at Albuquerque. Isobars (solid lines) are drawn for every 4 mb and 1000-500 mb thickness (dashed lines) are at 6 decimeter intervals. Thickness field was obtained by subtracting composite 1000 mb height from composite 500 mb height.

layers. Cold air advection may be present at the surface with strong warm air advection near and above the 850 mb level.

To create heavy snow at Albuquerque, unusual circumstances must exist. This is supported by the small number of heavy snow occurrences during the past 28 years. During this time, heavy snow has fallen on the average of once every 2.55 years. Grice (14) found that even with high precipitable water and an approaching vorticity center, the 12 hour precipitation rate would probably be about one-half required for heavy snow. Grice also indicated that the heavier precipitation generally occurs with less atmospheric moisture.

Gregg (15) found that with regard to precipitation, the synoptic-scale disturbances of the winter season seldom yield appreciably greater areal coverage in New Mexico than the air-mass types; generally 20 percent or less. Jorgensen, Klein and Korte (2) found that the heavier precipitation in the intermountain areas of the West are associated with the more intense lows and Williams and Peck (6) stated that " 'cold low' formations over the western plateau are usually the result of strong baroclinic situations, with pronounced deepening of an upper-air trough as it moves in from the west coast." They also indicated this type system is associated with strong vorticity advection resulting in pronounced large-scale upward vertical motion. From the available data it appears this type of system (although the trough may not deepen into a "cold low") is usually required for heavy snow to develop at Albuquerque.

From the individual cases it appears strong vorticity advection prevailed over Albuquerque during the heavy snow. In each of the cases, a vorticity "lobe" was situated immediately upstream and effectively increased the strength of the positive vorticity advection over the station. The upward vertical motion at the 500 mb level was probably enhanced by the divergence at 300 mb associated with the maximum winds.

Younkin (13), and Shaw and White (16) stressed the relation on vorticity centers to areas of heavy snow in the western United States and New Mexico respectively. Both studies found that heavy snow tended to occur just to the left of the vorticity track, but Shaw and White indicated heavy snow was possible through a large area downstream of the vorticity center.

Grice (14) utilized a grid establishing Albuquerque at the origin and the abscissa parallel to the 12 h vorticity track. Grice found that for heavier precipitation amounts, the vorticity center positions were in basic agreement with the results of both Younkin, and Shaw and White. Although vorticity analyses were available for only four cases, the results were quite similar (Figure 9).

The circulation in the lower levels cannot be overemphasized (16). The general terrain around Albuquerque ranges from 2000 m to 2500 m (Figure 1) with individual mountains to above 3000 m. During heavy snow, winds below 3000 m at Albuquerque (excluding surface winds) are generally light. This is indicated by the average 700 mb chart (Figure 4) and supported by the four individual cases. Soundings made during the heavy snowfall revealed wind speeds generally less than  $10 \text{ m s}^{-1}$  below 3000 m. The probable effect

of the light winds is to minimize downslope conditions.

Favorable convergence near the surface is required for widespread heavy snow to develop over New Mexico (16). The occurrence of a surface trough in western New Mexico (Figure 6) supplies the low-level convergence. However, high pressure should be situated to the east of New Mexico to supply low-level moisture into the state. The importance of this surface pattern to precipitation in New Mexico has long been recognized (17).

The importance of low-level moisture to heavy, widespread precipitation over New Mexico was stressed by Grice (18). Figure 8 suggests that low-level moisture must be supplied from the southeast with associated warm air advection. Klein (10), using the local component of anomalous 700 mb flow conducive to heavy precipitation in winter, indicated Albuquerque to be in an area absent of any predominant direction. However, a southeast direction predominated just south of the station and an east direction predominated just to the northeast of the city. Klein also showed the Gulf of Mexico to be the origin of the anomalous 700 mb flow favorable to heavy precipitation in central New Mexico. Examination of all nine cases since 1950 suggested that low-level moisture was advected over Albuquerque from the east, southeast or south. Although moisture in the middle and upper troposphere can move into central New Mexico from the southwest, in all nine heavy snow cases low-level moisture was available in western Texas or northern Mexico.

#### 4. CONCLUDING REMARKS

Heavy snow at Albuquerque is not a common occurrence and the conditions which cause the precipitation are unique. The upper-air pattern is dominated by a southeast moving and usually deepening low or trough over the western United States which turns to the east or northeast over eastern Arizona or western New Mexico. Heavy snow at Albuquerque is related to strong positive vorticity advection in the upper atmosphere as well as divergence associated with maximum winds at 300 mb.

Heavy snow appears to be strongly related to light winds below 3000 m which essentially eliminate downslope conditions. Surface convergence is provided by a surface trough near or just to the west of Albuquerque and low-level moisture is probably advected into central New Mexico from the east, southeast or south by the flow pattern of a high pressure ridge east of the state.

The combination of synoptic patterns which create the heavy snow at Albuquerque probably persist only a short period. For the nine cases, the average time of snowfall was only 12 hours with heavier snow several hours shorter. The slowing of the upper-level low as it recurves probably provides the necessary time for the heavy snow to occur. The importance of a slow moving upper-level low to heavy snow in New Mexico was mentioned by Grice (18) and Brown and Brintzenhofe (9).

One or more of the above conditions commonly develops during the winter months. However, it appears from available data, that all conditions should exist for heavy snow to fall on Albuquerque. Because of terrain similarities, the conditions listed in this study are

