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A STUDY OF WIND GUSTS ON LAKE MEAD

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ABSTRACT. A number of pairs of different independent parameters from the Yucca Flat soundings are used as the dimensions on a computer plot of the occurrences of gusty winds on Lake Mead. The study was limited to the months from April through September and covered the years from 1967-1973. The 12Z sounding was used with the observed winds used being limited to 18 hours subsequent to the sounding.

Varying results were obtained with several plots indicating promise, while others showed no identifiable relationship. The comparisons that showed favorable results include "'Total-Totals' vs. 700-mb Dew-Point Depression" and "700-mb Dew-Point Depression vs. 500-mb Dew-Point Depression". The study seems to indicate a need for a reasonably dry lower layer with a moist layer above. It was also shown that values of instability indexes should be reasonably high if the gusts are likely to occur. These characteristics are easily identifiable and should prove as a positive aid to the forecaster, not only at Las Vegas but to all those in the intermountain region where this type of gust frequently occurs.

I. INTRODUCTION

This Technical Memorandum deals with a study of the winds observed on Lake Mead, the reservoir created by Hoover Dam in 1936. For a detailed description of the topography of the area, see R. P. Augulis (1968). The considerable boating activity on Lake Mead demands precise forecasting of the possibility of experiencing sudden gusty winds on the lake. The problem faced by the forecaster is that if he includes warnings too frequently in the forecast, the boaters become immune to these warnings, while on the other hand, he can't justifiably underforecast to compensate for this unfortunate reaction by the public.

The purpose of this project was to look at wind-run records for five stations and record the dates and times that each of these stations experienced strong, short-period, gusty winds. Then, by direct comparison with the upper-air soundings from Yucca Flats, Nevada, try to identify possible useful predictors for these dangerous, gusty wind regimes. It is hopeful that the results of this project will result in more confidence and reliability in the forecaster's warnings.

II. DYNAMICS

During the summer months the intermountain region experiences frequent air-mass thunderstorms. As a result of the very dry air common to the region, these storms commonly have bases ten to twelve thousand feet above the terrain. Unlike thunderstorms occurring in air containing more moisture, there is seldom heavy precipitation and it is not uncommon to have little or no rain at the surface. A very striking characteristic of these thunderstorms is the occurrence of strong gusty winds at the surface. These gusts, generally stronger than those observed with wet thunderstorms, cannot be entirely attributed to the drag force of the liquid droplets as the rain is frequently nonexistent five or six thousand feet below the cloud base (W. R. Krumm, 1954). It has been suggested that the evaporative cooling of the droplets will quickly lower the air to its wet-bulb temperature in successive levels as it descends in the rain shaft. This would account for the rain shaft air rapidly becoming much colder and heavier than the surrounding environment. Byers and Braham (1949) have suggested this as a contributory factor even in moist thunderstorms, although with a generally smaller environmental lapse rate the difference in density would not be as great, yielding less negative buoyancy. Observations indicate that there is an accompanied jump in the surface pressure, often as much as several millibars (MacDonald, 1976). MacDonald suggests that a small but intense meso-high develops on the surface and, thus, produces a strong divergent wind. It was with this in mind that the project was undertaken. The selection of parameters in the study was made in a way that would best support or discount this dynamic explanation as the cause for the strong gusty winds.

III. DATA

The data used for this project were composed of two basic sets. The first included wind-run records from five stations, four of which were on the lake, and the fifth being located at the North Las Vegas Air Terminal (see Figure 1).

The wind records were on pressure-sensitive tape from surplus German recording instruments. These instruments are similar, both in operation and reliability, to the present wind instruments. The wind records for each station were incomplete and the period of record varied between individual stations. The years with the best coverage by all stations were 1969 through 1972 and for that reason were selected for use in the project. Seasonally, the period from April 1 to September 31 was chosen in an effort to eliminate the influence of the more typical winter wind patterns.

The instrumentation used recorded wind-run and in so doing acts to damp out the evidence of gusty winds. In an effort to identify those short-period gusty winds, a selection of a few guideline characteristics were set for what was felt the desirable wind regime. These could be stated as follows:

1. an average wind speed greater than 20 kt for a short period of time.

2. a relatively sharp increase to, and the decline from, the maximum average wind.

3. maximum strength periods that generally lasted less than one hour.

With these in mind each tape was visually analyzed and when it was felt that such a wind regime had been located on the tape, a measurement of the shortest distance between any two wind-run lines was measured in one-five-hundreths of an inch increments (see Figure 2) and recorded as a whole number, along with date, hour, and station where it was measured. This procedure for measuring the gusty wind periods gave a varied solution proportional to the wind speed. For the strongest winds recorded (>80 kt) a resolution of 3.5 minutes was attained, while for the slower winds (<30 kt) it approached sixteen minutes.

After going over all the tapes, there were 97 cases in which it was felt all the specifications stated were met. These cases were then recorded on computer punch cards, completing the first main set of data.

The second set of data was the upper-air soundings from Yucca Flats. These were obtained from the National Climatic Center in Asheville, North Carolina. The records were recorded on 9-track tape in a card-deck format and included the 00Z and 12Z soundings for the period 1967-1973.

IV. METHOD OF ANALYSIS

To find some reliable correlations between variables from the upper-air soundings and the occurrences of gusts at the nearby surface stations, there was a definite need for the use of a computer to handle the large quantity of data. The two sets of data were translated into the same format and together formed the block of data that was to be used in the analysis. It was felt that a scatter diagram with independent variables from the upper-air soundings on the axes and the occurrences of wind gusts as the dependent variable might show the correlations sought. Only the 12Z sounding was used for the upper-air data as it best represents the atmosphere for the afternoon and evening period during which the greatest percentage of gusty wind cases were recorded. Only those gust cases that occurred in the subsequent eighteen hours to the 12Z sounding were used.

The procedure the program was designed to go through in determining the scatter diagram first determined a position in a two-dimensional array from the independent variables from the sounding and then stored a value in this location dependent upon the occurrences of gusts on that day. The independent variables, that were individually chosen for each case, were read from the 12Z-sounding data and initialized to the first day of the chosen period (i.e., April 1, 1969). The program then searched the "wind data" to see if there had been any gusts recorded in the subsequent eighteen hours. If none of the five stations had experienced the desired wind pattern, then a zero was stored at that location in the array. If one or more of the stations recorded gusts, then the tens value of the strongest gust was entered and if more than one station reported gusts, the number of stations was also entered--separated from the gust value by a comma. For example, "4,2" represents a strongest gust value between forty and fifty knots, with two stations reporting gusts. After going through the entire data period, the array is printed out with the appropriate scales and labels. When filling the array, the program allows a zero to be replaced by another symbol but will not allow a zero to replace a position already filled with a non-zero value. This is in order to prevent the loss of wind gust values when the same position is filled more than once.

V. RESULTS

From the data base there were seven scatter diagrams studied for the project. The independent parameters were selected in a way that was felt would best support or disprove the basic ideas held about the mechanisms behind these gusty wind regimes. The seven scatter diagrams had the occurrences of gusts as the dependent variables and the following independent variables:

Diagram 1. "total-totals" vs. 700-mb dew-point depression.

Diagram 2. 700-mb dew-point depression vs. k-values.

Diagram 3. 700-mb dew-point depression vs. 500-mb dew-point depression.

Diagram 4. 700-mb wind speed vs. k-values.

Diagram 5. 700-mb wind direction vs. 500-mb wind direction.

Diagram 6. 700-mb wind direction vs. 700-mb dew-point depression.

Diagram 7. 500-mb wind direction vs. k-values.

A complete discussion of each comparison, covering positive and negative results combined with possible explanations for the results, will be done on an individual basis. The ordering will be that of the preceding list.

1. "Total-totals" vs. 700-mb dew-point depression:

This selection of independent variables appears to be very valuable in the analysis of this project. There appears to be two important correlations present on the diagram. The diagram has been divided into three areas that are labeled A, B, and C. These areas were chosen as a result of the distribution of wind gusts. Approximately 10% of the wind-gust cases fell in each of areas A and C, with the remaining 80% falling in Area B. A large percentage of zeros are found in area A. Especially keeping the fact in mind that each zero on the diagram, proportional to the concentration of zeros in that area, can represent more than one sounding with this position in the array. Under this consideration, it is likely that a large portion of the test days fall in area A, yet only 10% of the gust records fall in this area. In comparison, a similar number of days likely fall in area B with 80% of the records. Area C only represents 10% of the gust records but in comparison only includes a very small number of test days; likely, making it the highest occurrence area on the diagram. It is of interest to note that the extreme gust (8,2) falls in this area.

By classifying the gusts as less than thirty or greater than thirty, there appears to be a discernible pattern in distribution. At the far left the majority of gusts fall in the less-than-thirty category but as one moves to the right a gradual transition occurs until the greater-than-thirty category prevails.

This distribution on the diagram tends to suggest that the higher the "total-totals" value is, the more likely it is that gusts will occur. More importantly, the drier the 700-mb level, the greater the risk of gusts for a like "total-totals". It also suggests that with a dry 700-mb level it is more likely that the gusts will be stronger than if the layer were moist. This may be explained by the difference in thunderstorms likely to occur for each condition (i.e., moist thunderstorms vs. dry thunderstorms). The dry thunderstorm's downdrafts being enhanced by evaporative cooling creating an increase in gusty surface winds over those resulting from moist thunderstorms.

2. 700-mb dew-point depression vs. k-values:

This diagram has also been divided into areas A, B, and C according to the values used in diagram 1. It is again interesting to note that the extreme gust (8,2) falls in area C. In this diagram it is of particular interest to note the fast decline in the k-value needed to keep the sounding in a high-occurrence area as the dew-point depression is increased. Recalling the expression that is used to calculate k-values,

$$k = T_{8.5} + T_{D8.5} - D_7 - T_5,$$

it can be seen that k-values are inversely affected by the value of the 700-mb dew-point depression (i.e., a drying of the 700-mb layer results in a lower k-value) and should, therefore, respond accordingly.

3. 700-mb dew-point depression vs. 500-mb dew-point depression:

The distribution of wind gusts is slightly more random in this diagram than the preceding two, but still appears to be useful in arriving at some other possible parameters. The greatest concentration of zeros is in the proximity of a twenty-degree depression for both layers while the concentration of gust records is located near a five-degree depression at 500 mb and a ten-degree depression at 700 mb. This would suggest an increase in moisture at both levels increases the likelihood of gusts. The distribution of gusts appears to be skewed towards a drier 700-mb depression indicating that the moisture in the lower levels is not as necessary as at 500 mb. This is also supported by the fact that 80% of the gust days appear to the upper left of the forty-five degree line.

4. 700-mb wind speed vs. k-values:

This diagram supports the previously discussed correlation relating the increased likelihood of gusts with an increase in k-values. The distribution with respect to wind speed is interesting in that it suggests a concentration of gusts for the lighter 700-mb winds. This is likely the result of a generally higher occurrence of light winds at 700 mb both for gust and no-gust days. There is, however, a definite absence of gusts when dealing with the strong 700-mb winds. This may be a contradiction to the idea that the momentum of a strong wind aloft is carried to the surface by downdrafts, increasing the surface winds. The distribution shown here possibly suggests that strong winds aloft can act to hinder the vertical development necessary for thunderstorm activity.

5. 700-mb wind direction vs. 500-mb wind direction:

On this diagram the highest concentration of gusts and the highest concentration of zeros do not appear to fall in the same location. The zeros are concentrated slightly to the right of the forty-five degree line where the wind increases direction with height while the gusts appear biased to the left where the winds are backing, decreasing direction with height. Approximately two-thirds of the gust-days fall on the backing side of the line.

6. 700-mb wind direction vs. 700-mb dew-point depression:

and

7. 500-mb wind direction vs. k-values:

These two diagrams to not appear to show any significant results. For this particular station, the prevailing wind seems to overpower any possible relationships. Diagram 6 does affirm the idea that a drier 700-mb layer enhances the chances for gusts, and Diagram 7 also reinforces the idea that k-values are directly proportional to the concentration of gusts.

VI. CONCLUSIONS

Each of these different comparisons seems to support the others and together emphasize a few important conditions that are very likely indicators of these strong, short period, gusty winds on Lake Mead. A summary of these possible indicators could be listed as follows:

1. A reasonably dry layer at 700 mb combined with a moist layer at 500 mb.
2. High values for the calculated instability indexes (k-values and "total-totals").
3. The absence of strong winds aloft.
4. A backing wind between 700 mb and 500 mb.

In the preparation of a forecast for winds on the lake, these points could be used as a guideline. On any particular day the more of these conditions that are met the greater the emphasis should be on the possibility for gusty winds.

VII. ACKNOWLEDGMENTS

The writer is indebted to Mr. Len Snellman and his staff at Scientific Services Division, Western Region Headquarters, for the opportunity to develop this project under their exceptional guidance. Special thanks for Dr. A. MacDonald of Scientific Services Division for his ideas, knowledge of the computer, and great patience.

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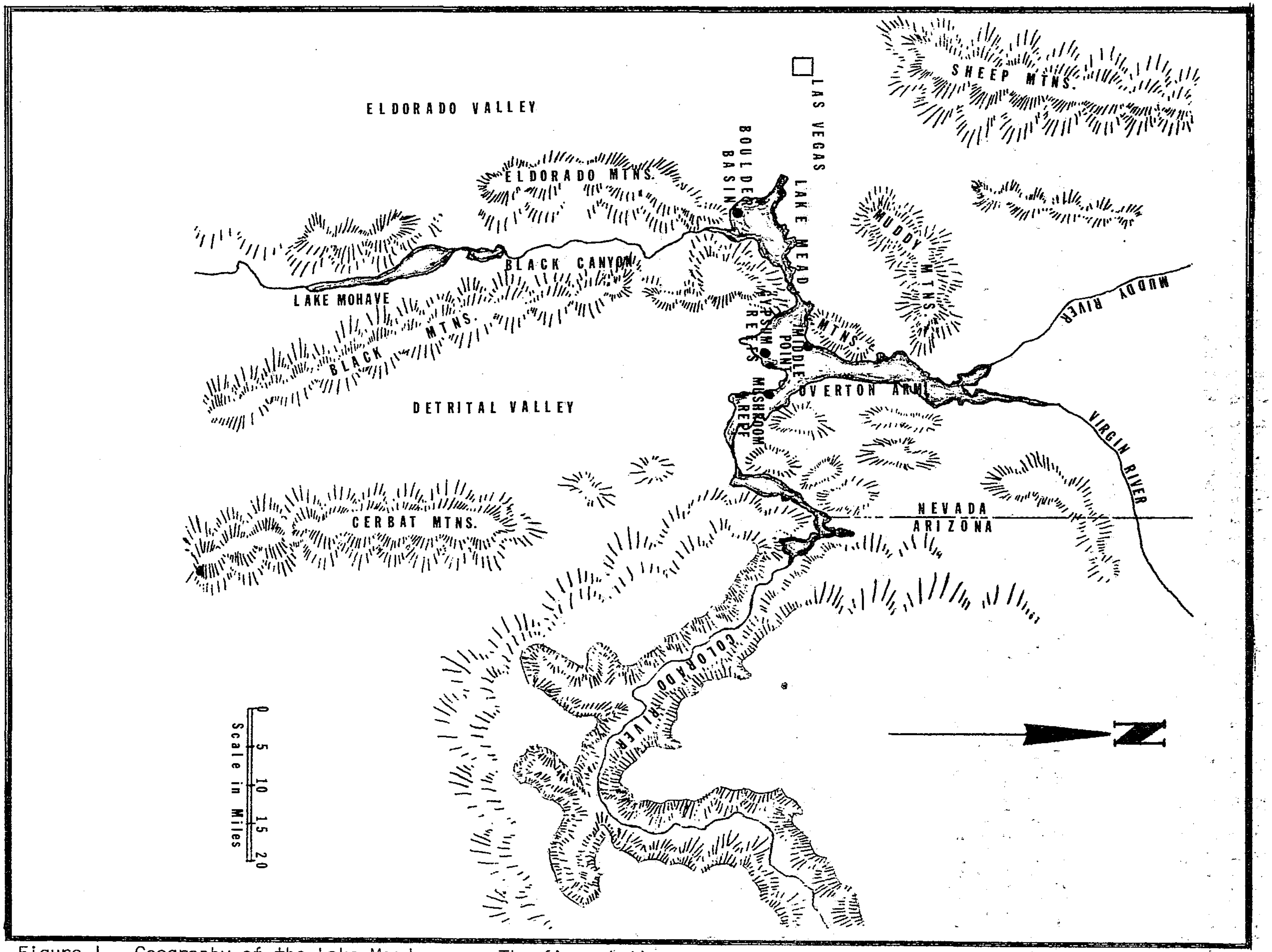
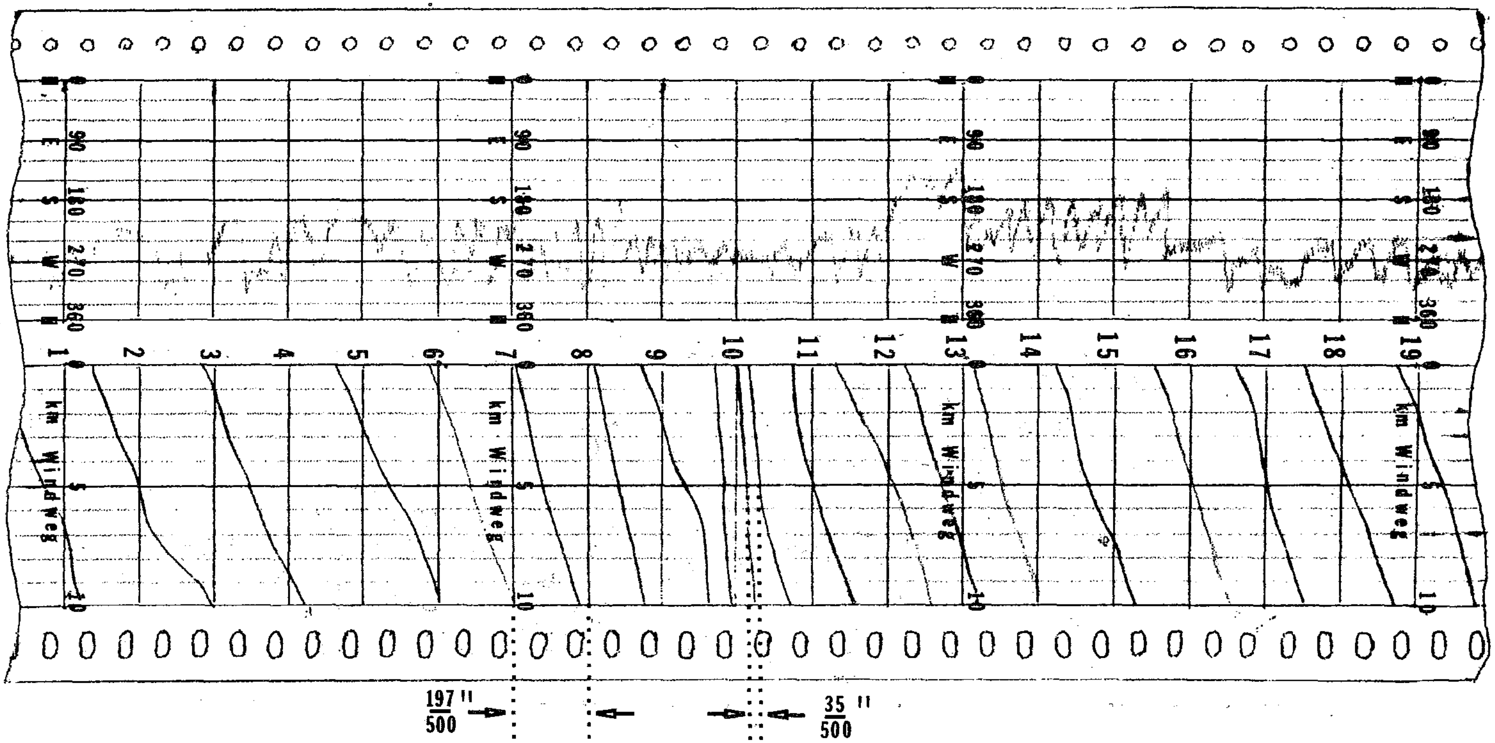


Figure 1. Geography of the Lake Mead area. The five stations used for data include the four shown on Lake Mead, plus the North Las Vegas Air Terminal.



THIS GUST CODED AS 35

AVERAGE SPEED IN KNOTS:

X = CODED VALUE

$$U = 1063.7/X$$

$$U = 30.4 \text{ KNOTS}$$

Figure 2. A portion of the tape used to find wind-gust data. Upper graph is for direction, and lower graph is for speed.

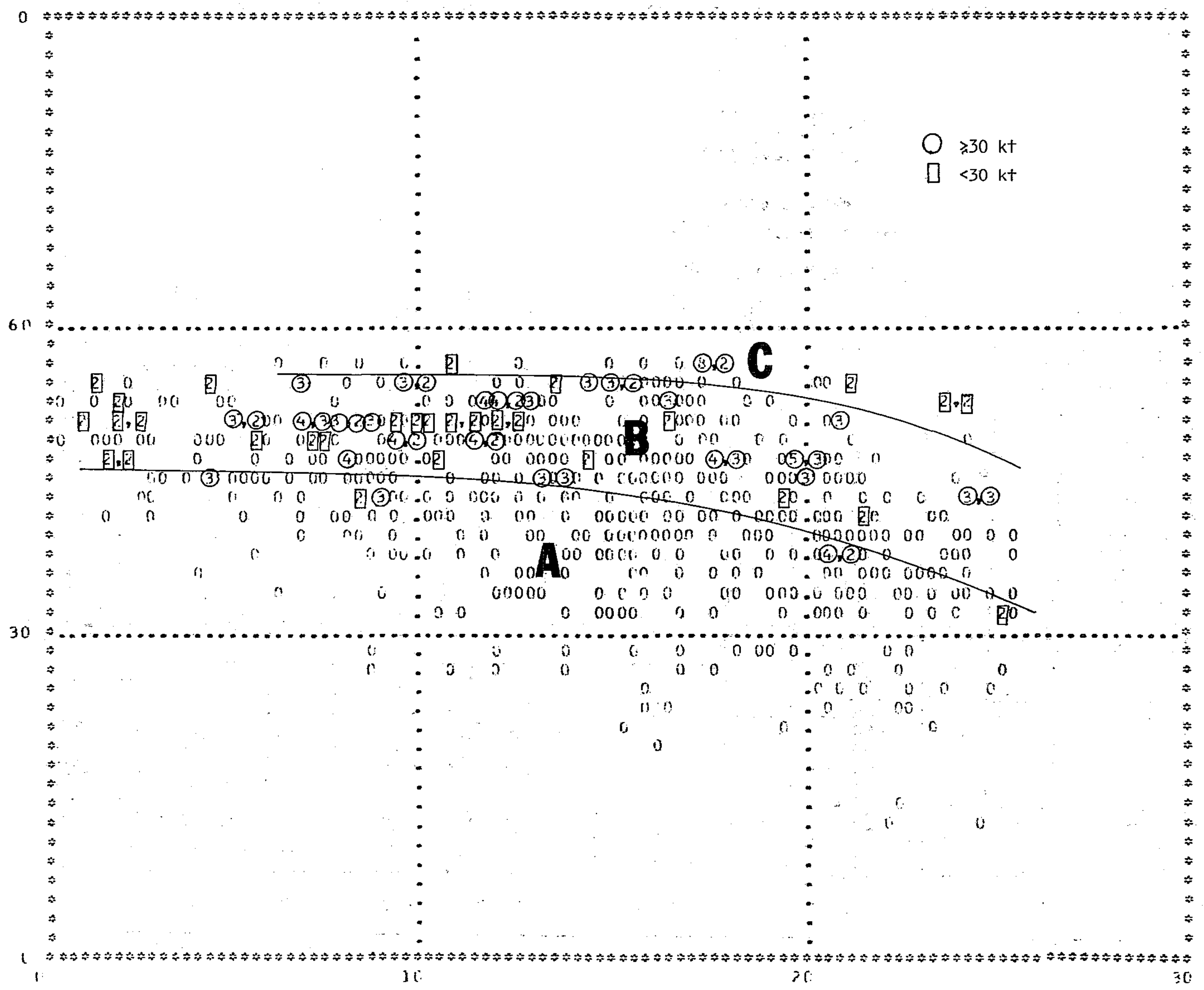


DIAGRAM I. "TOTAL-TOTALS" - ORDINATE VS. 700-MB DEW-POINT DEPRESSION - ABSCISSA.

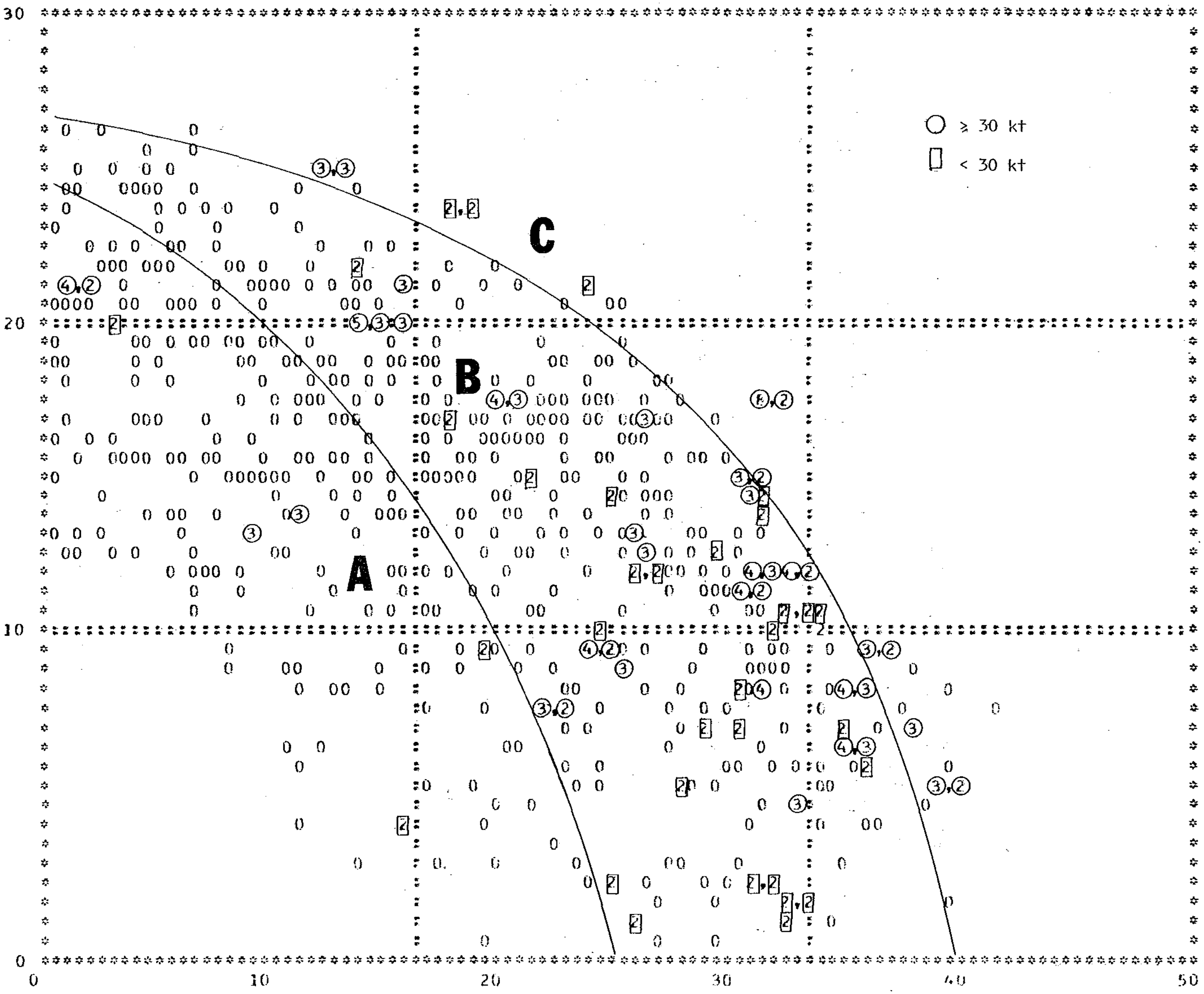


DIAGRAM 2. 700-MB DEW-POINT DEPRESSION-ORDINATE VS. K VALUE-ABSCISSA.

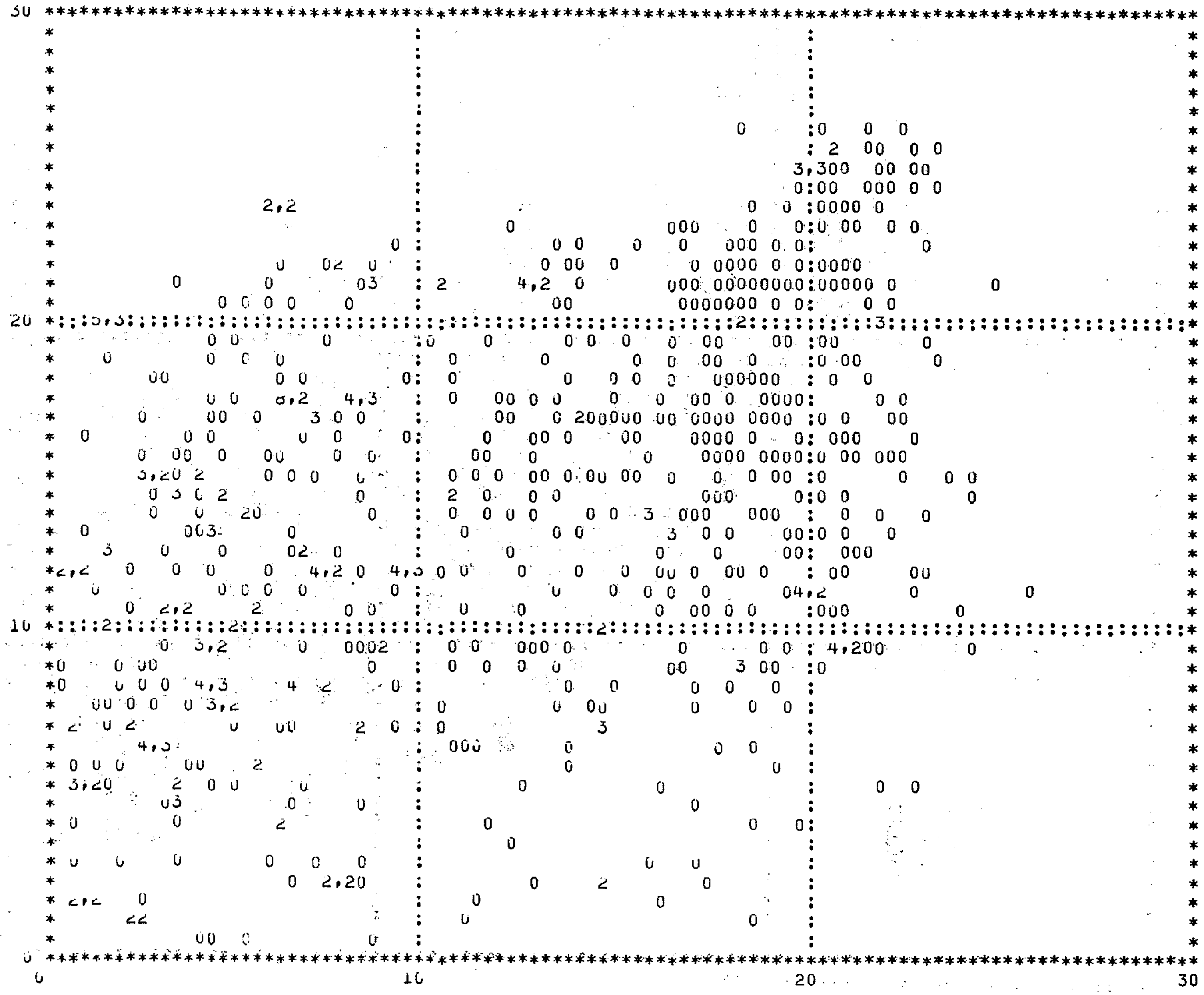


DIAGRAM 3. 700-MB DEW-POINT DEPRESSION-ORDINATE VS. 500-MB DEW-POINT DEPRESSION-ABSCISSA.

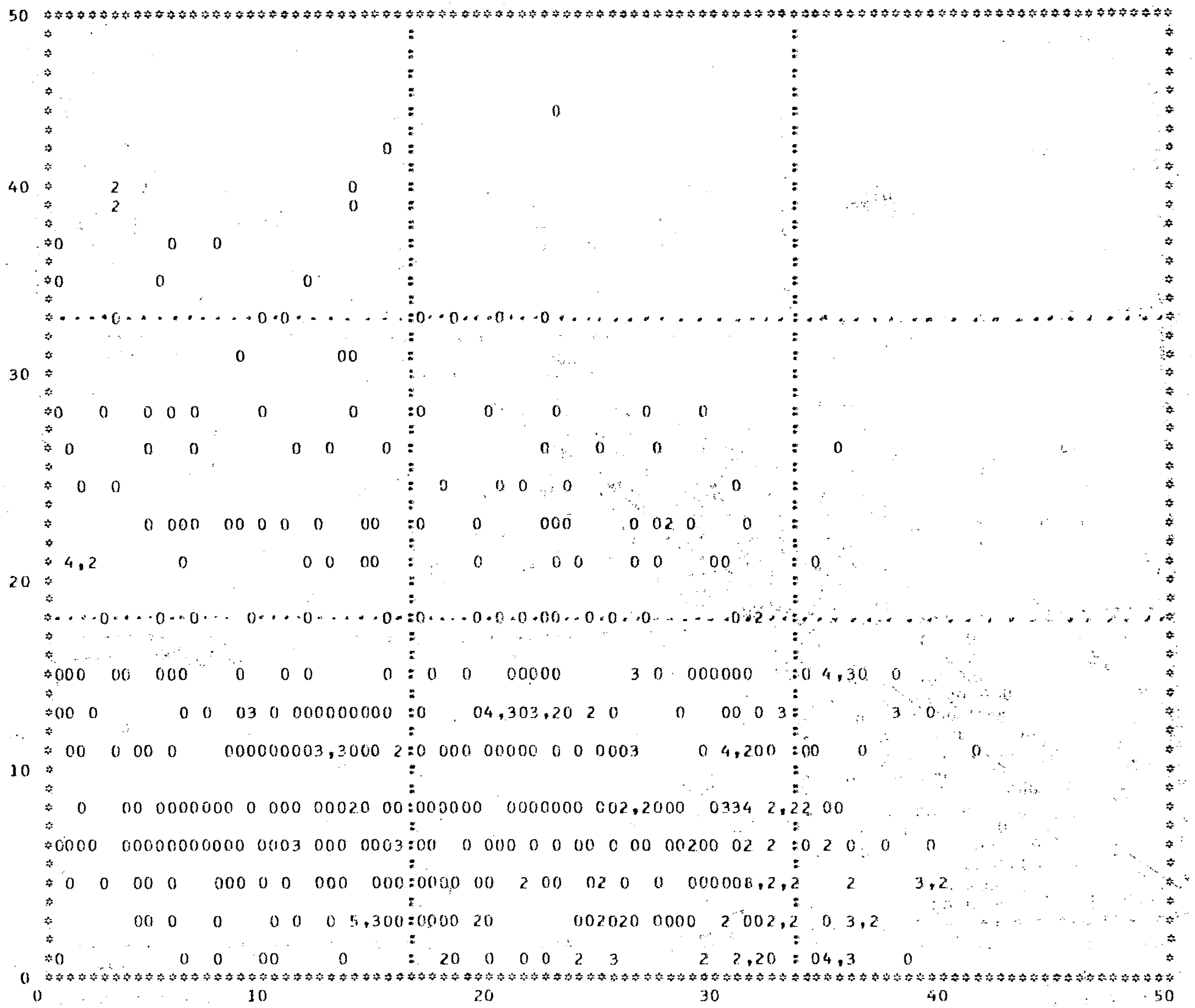


DIAGRAM 4. 700-MB WIND SPEED IN KNOTS VS. K VALUE-ABSCISSA.

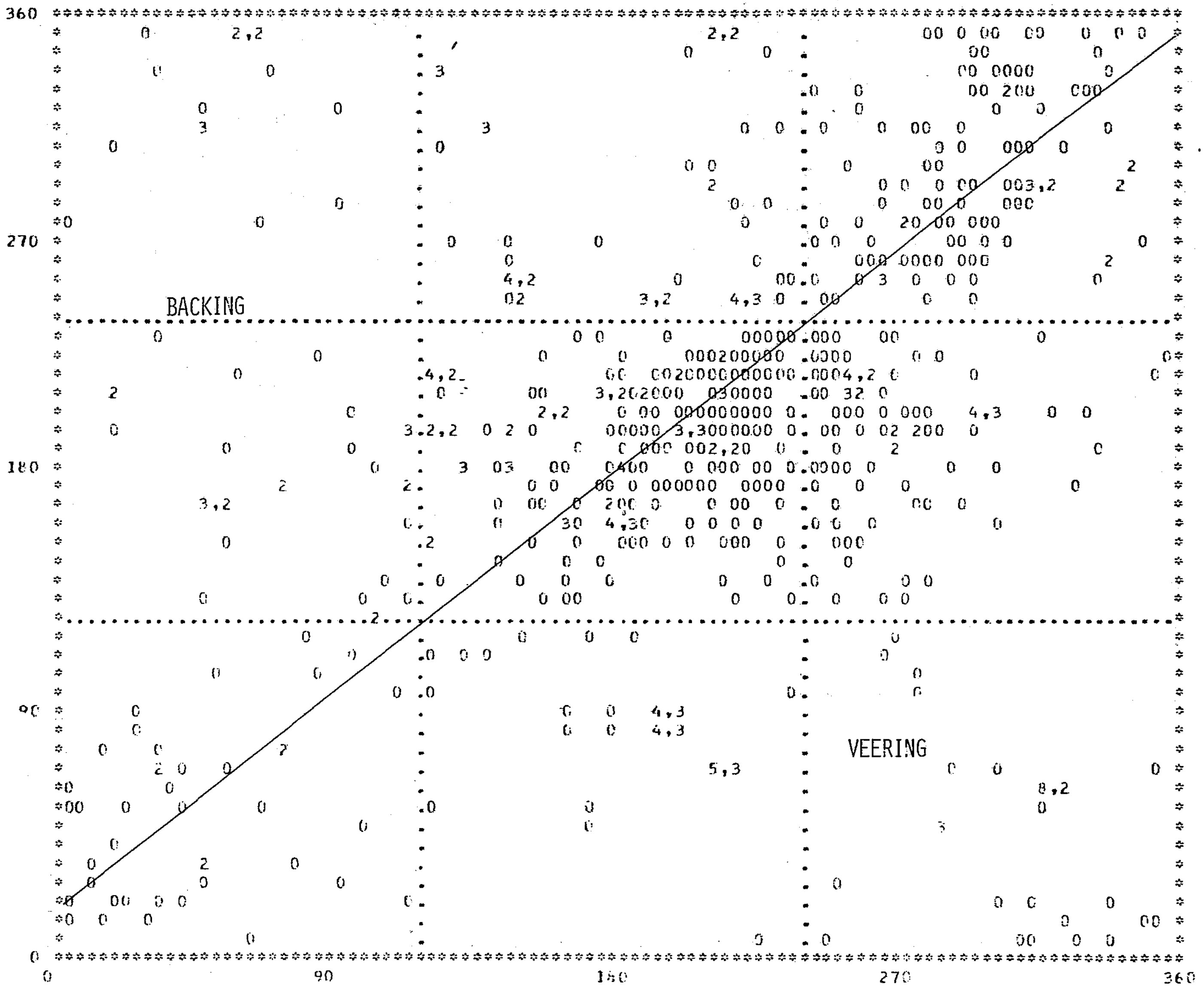


DIAGRAM 5. 700-MB WIND DIRECTION-ORDINATE VS. 500-MB WIND DIRECTION-ABSCISSA.

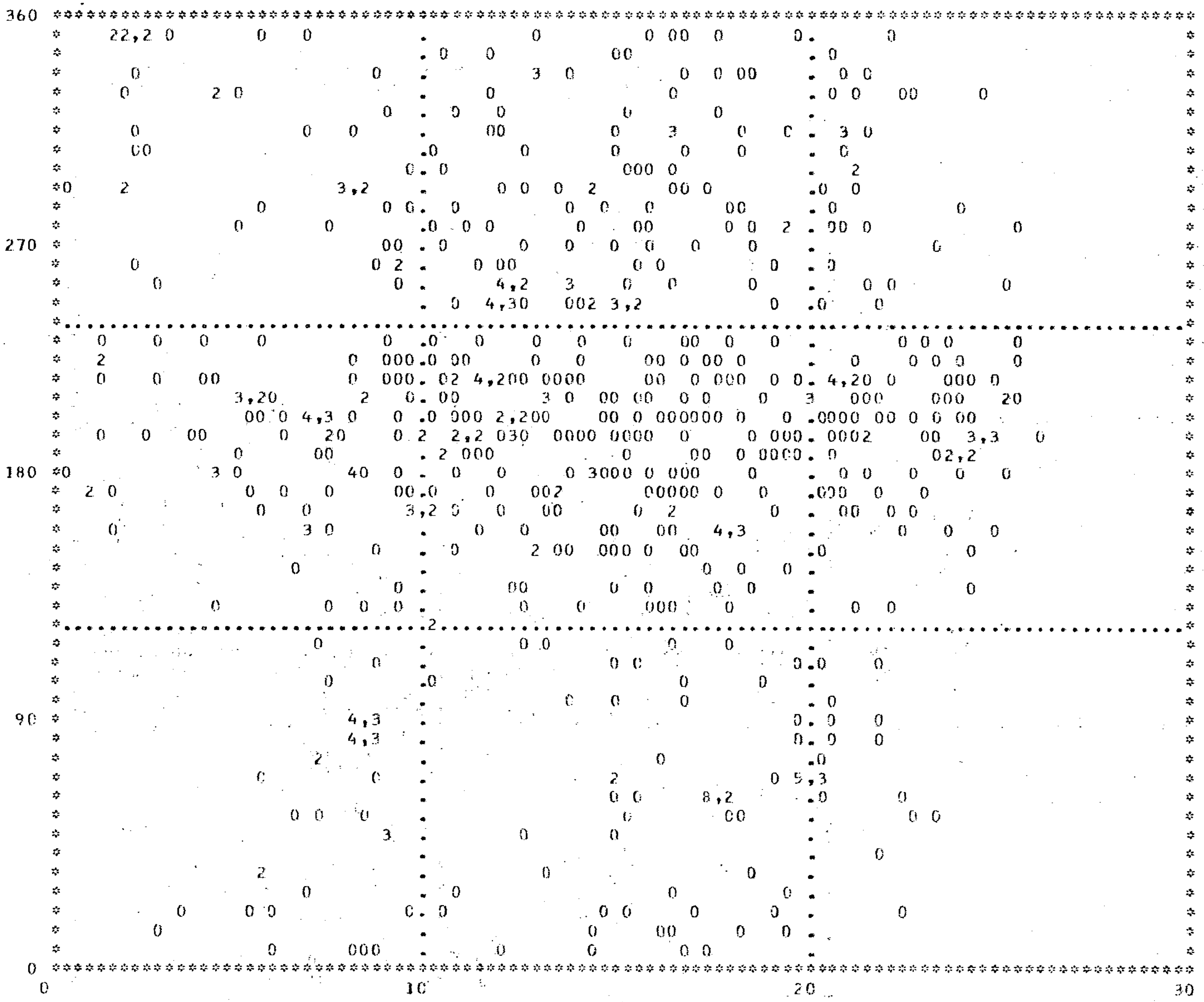


DIAGRAM 6. 700-MB WIND DIRECTION-ORDINATE VS. 700-MB DEW-POINT DEPRESSION-ABSCISSA.

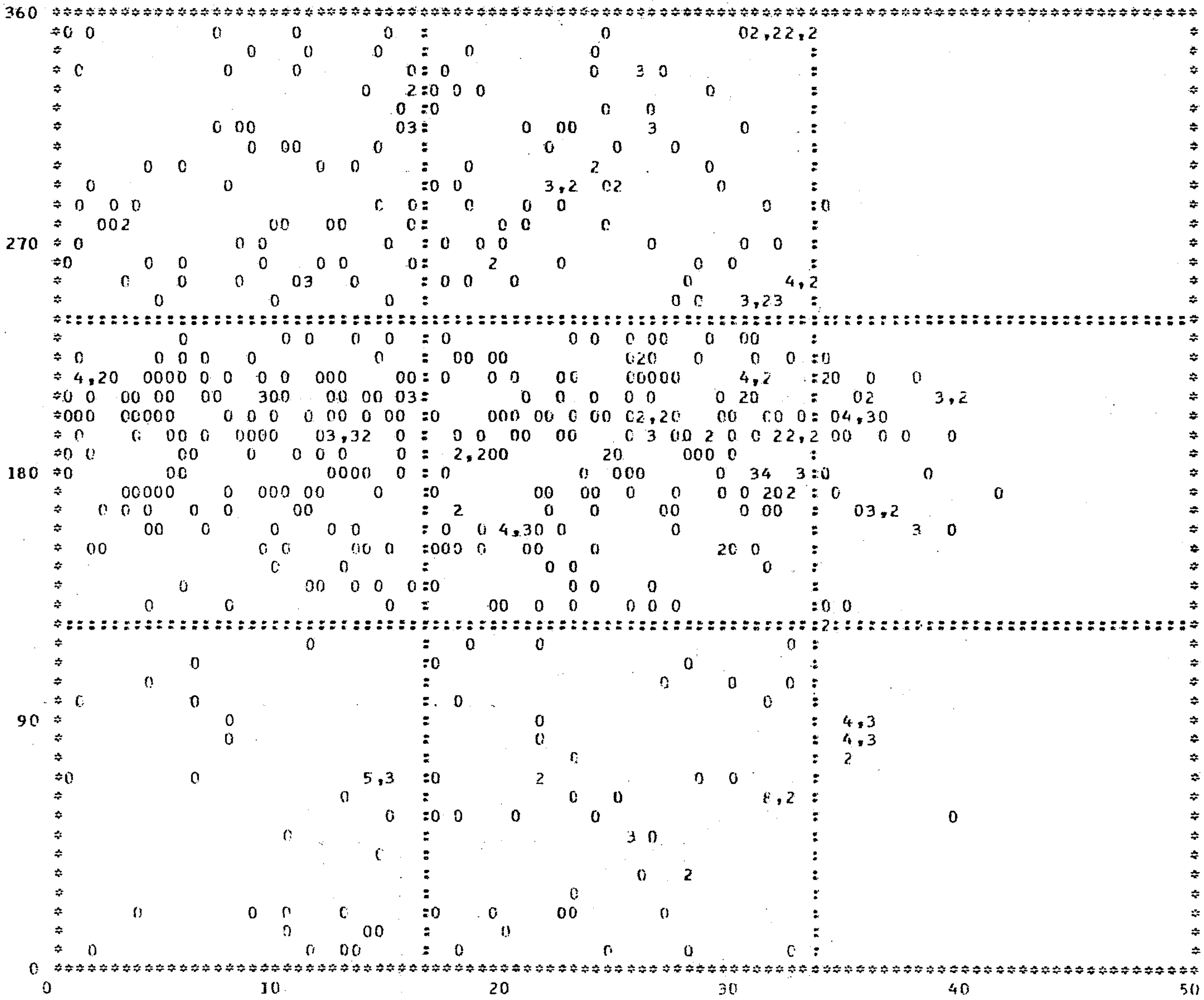


DIAGRAM 7. 500-MB WIND DIRECTION-ORDINATE VS. K VALUE-ABSCISSA.

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