A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NOAA Technical Memorandum NWS WR78

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

Forecasting Precipitation at Bakersfield, California, Using Pressure Gradient Vectors

EARL T. RIDDIOUGH

Western Region

SALT LAKE CITY,
UTAH

July 1972

NOAA TECHNICAL MEMORANDA
National Weather Service, Western Region Subseries

The National Weather Service (NWS) Western Region (WR) Subseries provides an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready, for formal publication. The series is used to report on work in progress, to describe technical procedures and practices, or to relate progress to a limited audience. These Technical Memoranda will report on investigations devoted primarily to regional and local problems of interest mainly to personnel, and hence will not be widely distributed.

Papers 1 to 23 are in the former series, ESSA Technical Memoranda, Western Region Technical Memoranda (WRTM); papers 24 to 59 are in the former series, ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM). Beginning with 60, the papers are part of the series, NOAA Technical Memoranda NWS.

Papers 1 to 23, except for 5 (revised edition) and 10, are available from the National Weather Service Western Region, Scientific Services Division, P. O. Box 11188, Federal Building, 125 South State Street, Salt Lake City, Utah 84111. Papers 5 (revised edition), 10, and all others beginning with 24 are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. Price: $3.00 paper copy; $0.95 microfiche. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda

WRTM 1 Some Notes on Probability Forecasting. Edward D. Diemer, September 1965. (Out of print.)
WRTM 2 Climatological Precipitation Probabilities. Compiled by Lucianne Miller, December 1965.
WRTM 3 Western Region Pre- and Post-FP-3 Program, December 1, 1965 to February 20, 1966. Edward D. Diemer, March 1966.
WRTM 4 Use of Meteorological Satellite Data. March 1966.
WRTM 5 Station Descriptions of Local Effects on Synoptic Weather Patterns. Philip Williams, Jr., April 1966 (revised November 1967, October 1969). (PB-178000)
WRTM 6 Improvement of Forecast Wording and Format. C. L. Glenn, May 1966.
WRTM 7 Final Report on Precipitation Probability Test Programs. Edward D. Diemer, May 1966.
WRTM 8 Interpreting the RAREP. Herbert P. Benner, May 1966 (revised January 1967). (Out of print.)
WRTM 9 A Collection of Papers Related to the 1966 NMC Primitive-Equation Model. June 1966.
WRTM 10 Sonic Boom. Loren Crow (6th Weather Wing, USAF, Pamphlet), June 1966. (Out of print.) (AD-479366)
WRTM 11 Some Electrical Processes in the Atmosphere. J. Latham, June 1966.
WRTM 12 A Comparison of Fog Incidence at Missoula, Montana, with Surrounding Locations. Richard A. Dightman, August 1966. (Out of print.)
WRTM 13 A Collection of Technical Attachments on the 1966 NMC Primitive-Equation Model. Leonard W. Snellman, August 1966. (Out of print.)
WRTM 14 Application of Net Radiometer Measurements to Short-Range Fog and Stratus Forecasting at Los Angeles. Frederick Thomas, September 1966.
WRTM 15 The Use of the Mean as an Estimate of "Normal" Precipitation in an Arid Region. Paul C. Kangieser, November 1966.
WRTM 16 Some Notes on Acclimatization in Man. Edited by Leonard W. Snellman, November 1966.
WRTM 17 A Digitalized Summary of Radar Echoes Within 100 Miles of Sacramento, California. J. A. Youngberg and L. B. Overaas, December 1966.
WRTM 18 Limitations of Selected Meteorological Data. December 1966.
WRTM 19 A Grid Method for Estimating Precipitation Amounts by Using the WSR-57 Radar. R. Granger, December 1966. (Out of print.)
WRTM 20 Transmitting Radar Echo Locations to Local Fire Control Agencies for Lightning Fire Detection. Robert R. Peterson, March 1967. (Out of print.)
WRTM 21 An Objective Aid for Forecasting the End of East Winds in the Columbia Gorge, July through October. D. John Coparanis, April 1967.
WRTM 22 Derivation of Radar Horizons in Mountainous Terrain. Roger G. Pappas, April 1967.
WRTM 23 "K" Chart Applications to Thunderstorm Forecasts Over the Western United States. Richard E. Hambidge, May 1967.

ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM)

WBTM 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman, July 1967. (PB-178071)
WBTM 25 Verification of Operational Probability of Precipitation Forecasts, April 1966-March 1967. W. W. Dickey, October 1967. (PB-176240)
WBTM 26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis, January 1968. (PB-177830)
WBTM 27 Objective Minimum Temperature Forecasting for Helena, Montana. D. E. Olsen, February 1968. (PB-177827)
WBTM 28 Weather Extremes. R. J. Schmidli, April 1968 (revised July 1968). (PB-178928)
WBTM 29 Small-Scale Analysis and Prediction. Philip Williams, Jr., May 1968. (PB-178425)
WBTM 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, U.S.A.F., May 1968. (AD-673365)
WBTM 31 Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky, July 1968. (PB-179084)
WBTM 32 Probability Forecasting--A Problem Analysis with Reference to the Portland Fire Weather District. Harold S. Ayer, July 1968. (PB-179289)
WBTM 33 Objective Forecasting. Philip Williams, Jr., August 1968. (AD-680425)
WBTM 34 The WSR-57 Radar Program at Missoula, Montana. R. Granger, October 1968. (PB-180292)
WBTM 35 Joint ESSA/FAA ARTC Radar Weather Surveillance Program. Herbert P. Benner and DeVon B. Smith, December 1968 (revised June 1970). (AD-681857)
WBTM 36 Temperature Trends in Sacramento--Another Heat Island. Anthony D. Lentini, February 1969. (Out of print.) (PB-183055)
WBTM 37 Disposal of Logging Residues Without Damage to Air Quality. Owen P. Cramer, March 1969. (PB-183057)
WBTM 38 Climate of Phoenix, Arizona. R. J. Schmidli, P. C. Kangieser, and R. S. Ingram. April 1969. (Out of print.) (PB-184295)
WBTM 39 Upper-Air Lows Over Northwestern United States. A. L. Jacobson, April 1969. (PB-184296)
WBTM 40 The Man-Machine Mix in Applied Weather Forecasting in the 1970s. L. W. Snellman, August 1969. (PB-185068)
WBTM 41 High Resolution Radiosonde Observations. W. S. Johnson, August 1969. (PB-185673)
WBTM 42 Analysis of the Southern California Santa Ana of January 15-17, 1966. Barry B. Aronovitch, August 1969. (PB-185670)
WBTM 43 Forecasting Maximum Temperatures at Helena, Montana. David E. Olsen, October 1969. (PB-185762)
WBTM 44 Estimated Return Periods for Short-Duration Precipitation in Arizona. Paul C. Kangieser, October 1969. (PB-187763)
WBTM 45/1 Precipitation Probabilities in the Western Region Associated with Winter 500-mb Map Types. Richard A. Augulis, December 1969. (PB-188248)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

NOAA Technical Memorandum NWSTM WR-78

FORECASTING PRECIPITATION AT BAKERSFIELD, CALIFORNIA, USING PRESSURE GRADIENT VECTORS

Earl T. Riddiough
Weather Service Office
Bakersfield, California

WESTERN REGION
TECHNICAL MEMORANDUM NO. 78

SALT LAKE CITY, UTAH
JULY 1972

TABLE OF CONTENTS

LIST OF TABLE AND FIGURES

FORECASTING PRECIPITATION AT BAKERSFIELD, CALIFORNIA, USING PRESSURE GRADIENT VECTORS

I. INTRODUCTION

The purpose of this study was to find an objective method of forecasting precipitation probabilities in the Bakersfield area. In considering readily available predictors, it was decided to use surface-pressure gradient vectors to give an indication of the approach and strength of low-pressure systems. The direction and magnitude of the resultant vector, using gradients from four quadrants, appeared to give the best results. While an objective method for a forecast of measurable precipitation for a period of 12 to 24 hours based on observed data was the prime concern, this system should also be adaptable to use with National Meteorological Center (NMC) facsimile prognostic charts for longer range forecasts. It was also felt this same system should be applicable to forecasting other elements, such as winds, temperatures, etc.

Rain occurs infrequently in the southern San Joaquin Valley; therefore it is of great importance when even a small amount occurs. Mountains surround Bakersfield on all sides except the northwest, which frequently results in a rain shadow over this area while surrounding areas receive precipitation. With the introduction of probability forecasting, there was very little material available to use in formulating an objective forecast. Since small-scale analysis seemed advisable for local forecasting, some objective method of forecasting was desirable for this station. Forecasters at Los Angeles, among other stations, had been using pressure differences between selected stations to arrive at a rain forecast [1]. Some experimentation had also been done at Bakersfield with pressure gradients; however, results were not satisfactory.

II. DEVELOPMENT OF OBJECTIVE AID

Pressure gradient vectors were plotted during the winter of 1964 - 65 in connection with the fruit-frost forecasting program to determine clear nights when radiation would be at a maximum [2]. In plotting these pressure gradient vectors on the surface maps, it was noted that there was a good correlation between direction of vectors and precipitation. During the winter of 1965 - 66 a new pattern of pressure gradients was set up and resultant vectors plotted on a circular graph along with precipitation during the following 12- 24-hour period. Results were very satisfactory.

Computation of pressure gradients used in the study during the winters of 1964 - 65 and 1965 - 66 required four stations equidistant from Bakersfield and at angles of nearly 90 degrees. Stations that fit this pattern best were Moffet Field (NUQ), Thermal (TRM), California, and Tonopah (TPH), Nevada. In the 4th quadrant, a point over the Pacific Ocean at 33 degrees north and 121 degrees west was selected (Figure 1). The pressure for this point was determined between NUQ and TRM, TPH, and 33N 121W in millibars and tenths. A resultant vector was obtained by the addition of these gradient vectors. A typical pressure pattern in which there was little chance of precipitation in the Bakersfield area is shown in Figure 2. It can be seen that with high pressure just to the north of Reno, the resultant pressure gradient vector points almost south. Thus, a resultant vector in this direction should give a very low probability of precipitation.

A typical rainy pressure pattern is shown in Figure 3. The resultant vector in this case was directed to about 330 degrees; this should be the direction for a high probability of precipitation at Bakersfield.

Resultant vectors were obtained from the 0400 PST and 1600 PST surface maps for each day of the 1964 - 65 season (November to April) and were then plotted on polar coordinate paper (Figure 4). Points at the end of each vector were marked either with an open circle showing no rain in the forecast period of 12 to 24 hours after maptime or a solid circle showing rain. Using this graph and counting the occurrences or nonoccurrences of precipitation for each forecast period in increments of 10 degrees of arc, the probability of precipitation (PoP) $\geq$.01 inch for the various portions of the chart was obtained. Average PoP values were then entered on the chart shown in Figure 5 for use in objective forecasting.

After examining data for the winter of 1966 - 67, it was decided there should be a correcting factor when the pressure was quite low or high in the Bakersfield area. When the pressure at Bakersfield at maptime was less than 1012 mbs, 10 percent was added to the objective forecast value and when pressure was above 1022 mbs, 10 percent was subtracted.

III. EVALUATION

A reliability curve for official Bakersfield WSO PoP forecasts for winter seasons 1965-66 and 1966-67 (November-April) is shown in Figure 6 (dashed line). Forecasts for this period were made before the objective aid was available. It can be seen that above 10 percent probability, the forecast curve is above the perfect reliability curve (underforecasting). No value greater than 60 percent was forecast for the 12 to 24 hour period. The reliability curve was then plotted for the objective method (solid line) for the November to April seasons from 1967 through 1971. It can be seen reliability was very good for PoP forecasts below 20 percent. Above this value there was a tendency for overforecasting of precipitation.

When evaluating objective forecasts with high PoP values, it was determined that when approaching low pressure systems were wet the objective method would provide reliable PoPs. When the systems were dry upstream, the objective method tended to overforecast precipitation. Forecasters at the station have used this information to subjectively improve the objective forecast over the past few years. The curve for the official forecasts (1967 - 71, dotted line) shows near-perfect reliability. This curve also gives a comparison against official forecasts made during the years of 1965 - 67 when no objective method was available (dashed line). The 1967 - 71 forecasts included several forecasts of seventy and eighty percent, while there were none above sixty percent when the objective method was not available.

A comparison between official and objective forecast scores for the period 1967 through 1971 is shown in Table I. It can be seen that official forecasts were better than objective forecasts--thus, forecasters were able to successfully modify the objective forecasts, using the criteria described earlier.

A plotting board for finding the resultant pressure gradient vector was devised as shown in Figure 7. The circular plastic scale shown at the bottom of the page was fastened to a plotting board and the circular plastic plate at the top of the page was mounted on top so it could rotate. Using this plotting board resultant pressure gradient vectors could be computed easily.

IV. CONCLUSIONS

In comparing the official forecast reliability curve before the objective forecast method was available against the curve afterwards, it can be seen that the objective method was a great help. I feel a similar objective method could be set up at other stations and would give more consistent forecasts and would be of great help when new men transfer into a station.

V. ACKNOWLEDGMENTS

Acknowledgments are due Mr. Ray Randall, MIC, Bakersfield, for his encouragement in this study; to Mr. Tom Crossan, MIC, Fresno, for his help in designing the vector plotting board and to the staff of the Bakersfield Weather Service Office for plotting the resultant pressure gradients during the years of study.

VI. REFERENCES

[1] THOMPSON, J. C. "A Numerical Method for Forecasting Rainfall in the Los Angeles Area". Monthly Weather Review, Vol. No. 7, Pages 113 - 124, July 1950.

[2] RIDDIOUGH, E. T. "Forecasting Minimum Temperature for Bakersfield, California". (Unpublished.) Presented at Fruit-Frost Conference, Pomona, California, 1965.

TABLE I

FORECAST VERIFICATION, BAKERSFIELD, CALIFORNIA
NOVEMBER - APRIL, 1967 - 71

	Official Forecasts	Objective Forecasts
Percent correct	90%	88%
Postagreement	.57	.44
Prefigurance	.50	.36
Threat Score	.36	.25

N = 1450

Precipitation Occurrences = 157

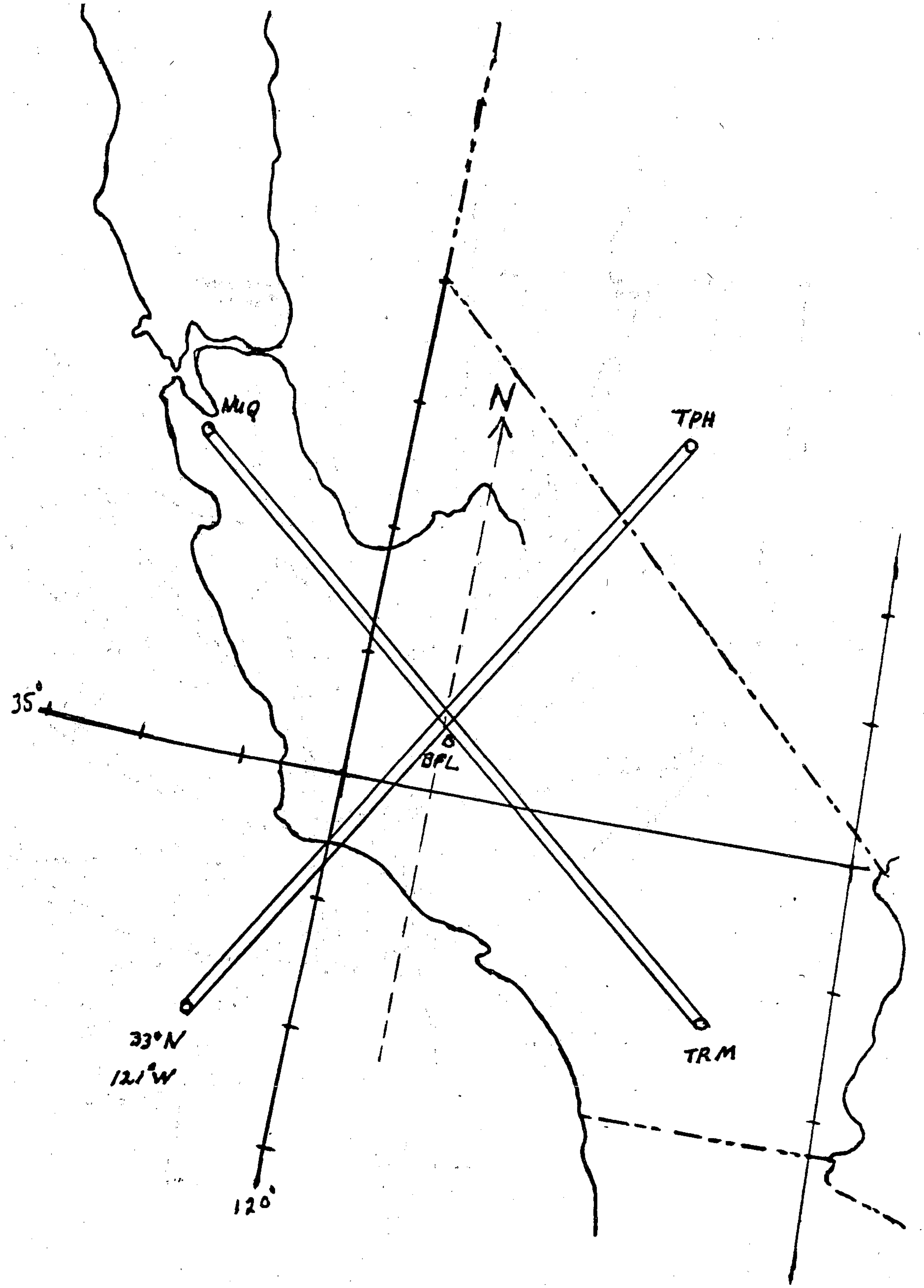

FIGURE 1. LOCATION OF STATIONS USED FOR PRESSURE GRADIENT COMPUTATIONS.

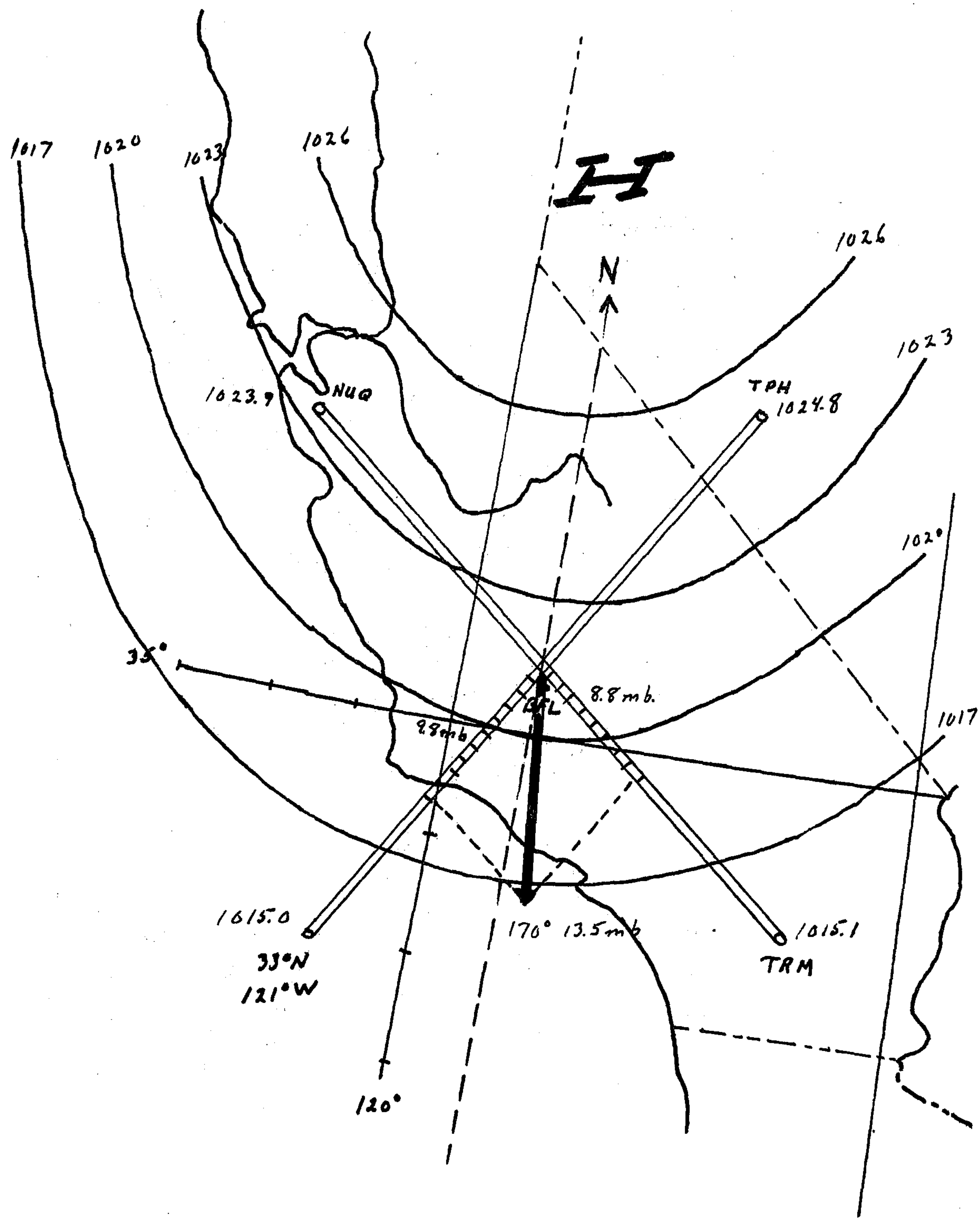

FIGURE 2. TYPICAL SURFACE MAP AND RESULTANT PRESSURE GRADIENT VECTOR FOR LOW PROBABILITY OF PRECIPITATION AT BAKERSFIELD, CALIFORNIA.

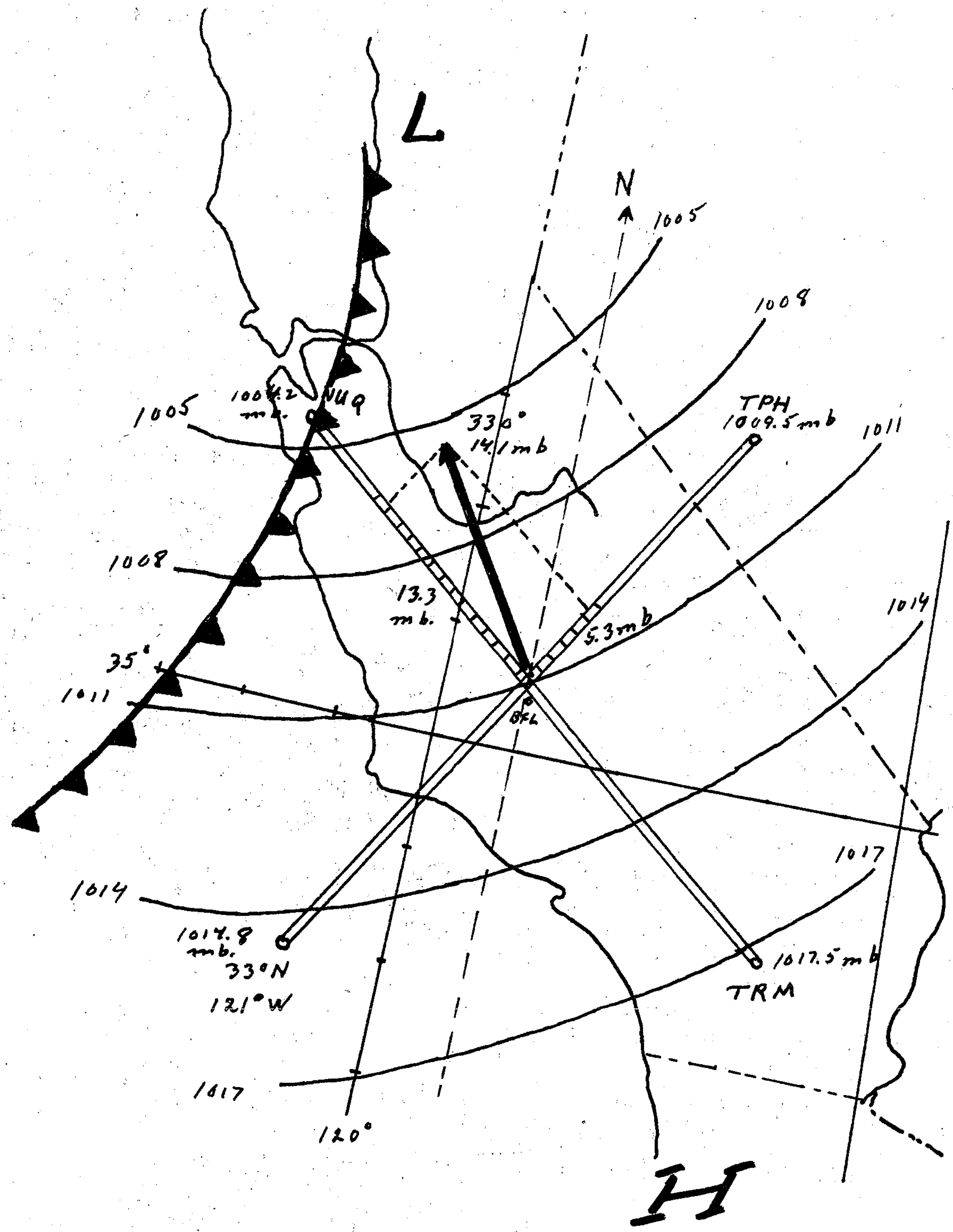

FIGURE 3. TYPICAL SURFACE MAP AND RESULTANT PRESSURE GRADIENT VECTOR FOR HIGH PROBABILITY OF PRECIPITATION AT BAKERSFIELD, CALIFORNIA.

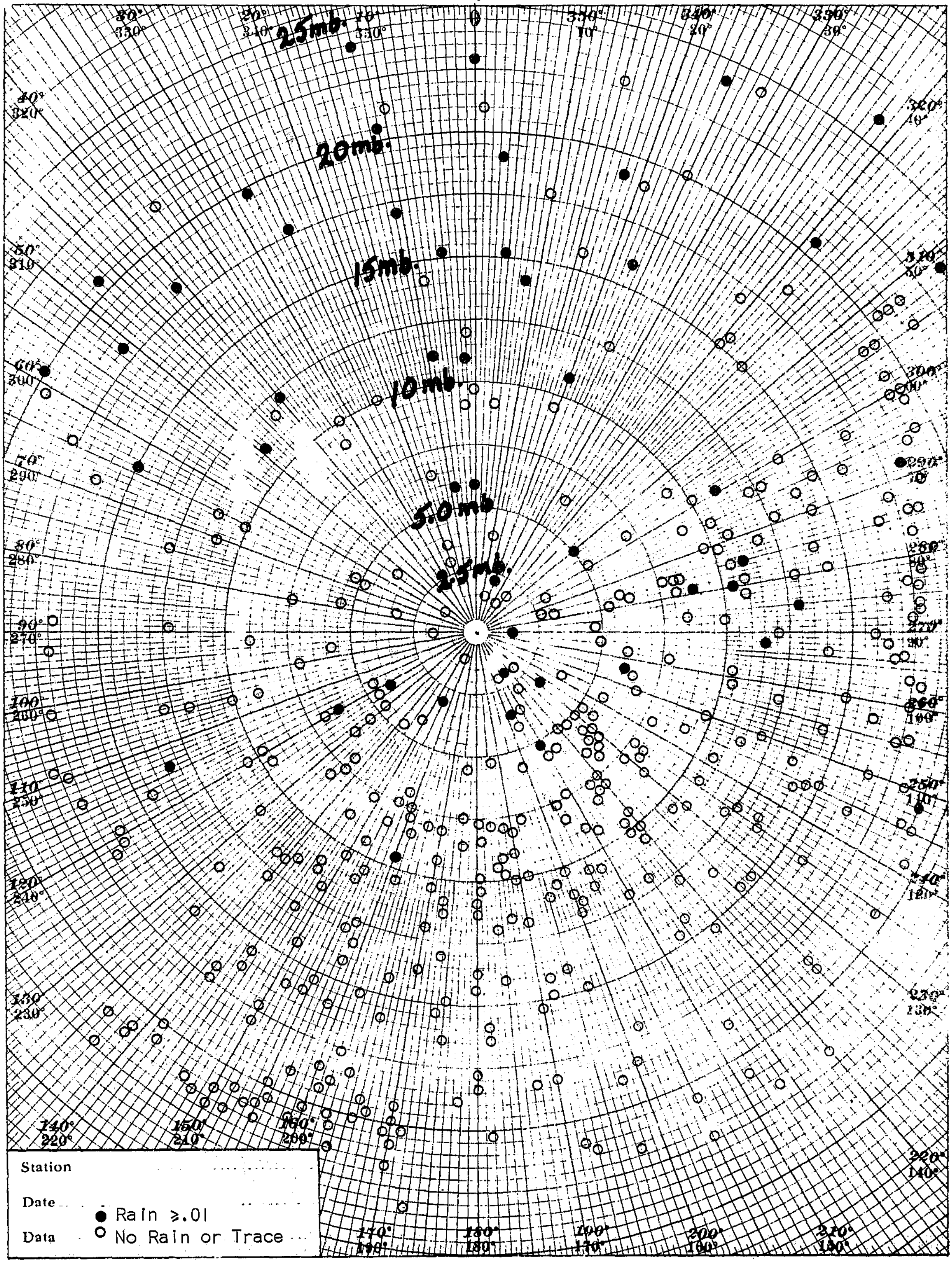

FIGURE 4. END POINTS OF RESULTANT VECTORS FOR SEASON NOVEMBER 1964-APRIL 1965. SOLID CIRCLE INDICATES RAIN FORECAST (≥.01) FOR 12 - 24 HOUR PERIOD; OPEN CIRCLE, NO RAIN OR TRACE.

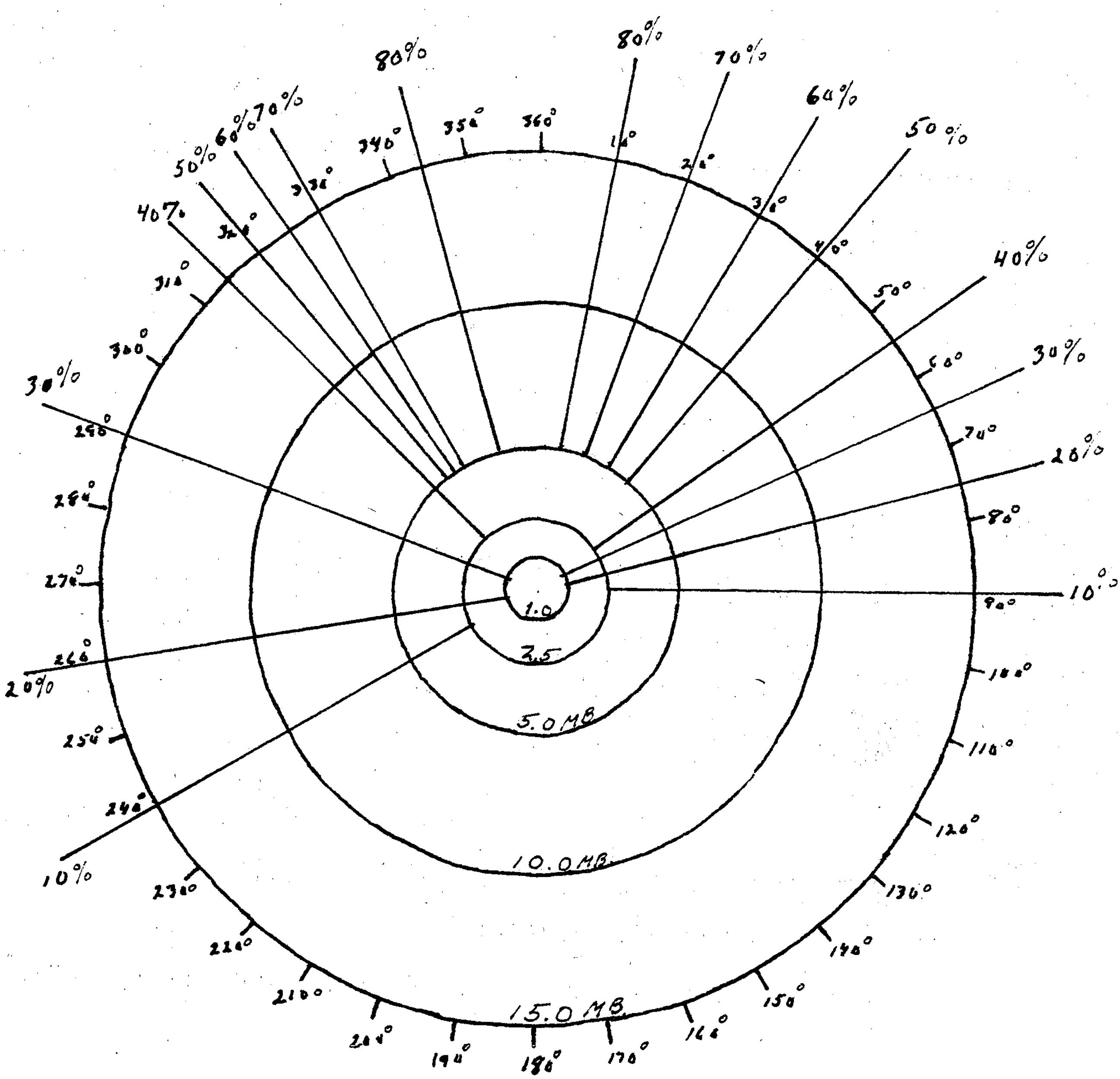

FIGURE 5. PROBABILITY OF PRECIPITATION AT BAKERSFIELD (NOVEMBER-APRIL) FOR RESULTANT SURFACE PRESSURE GRADIENT VECTORS WITH DIRECTION IN DEGREES AND MAGNITUDE IN MILLIBARS.

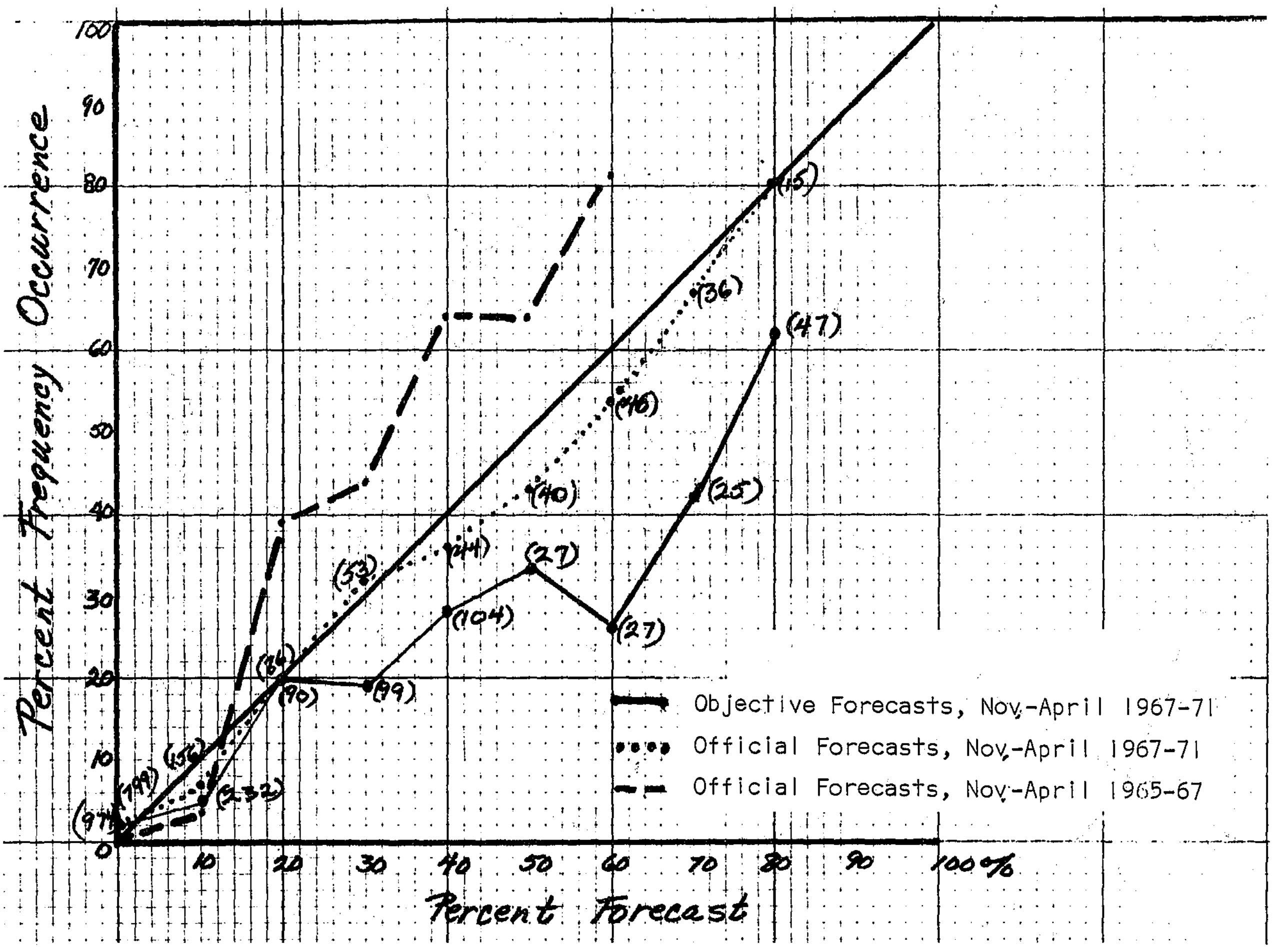

FIGURE 6. RELIABILITY CURVES FOR OBJECTIVE AND OFFICIAL PoP FORECASTS, BAKERSFIELD.

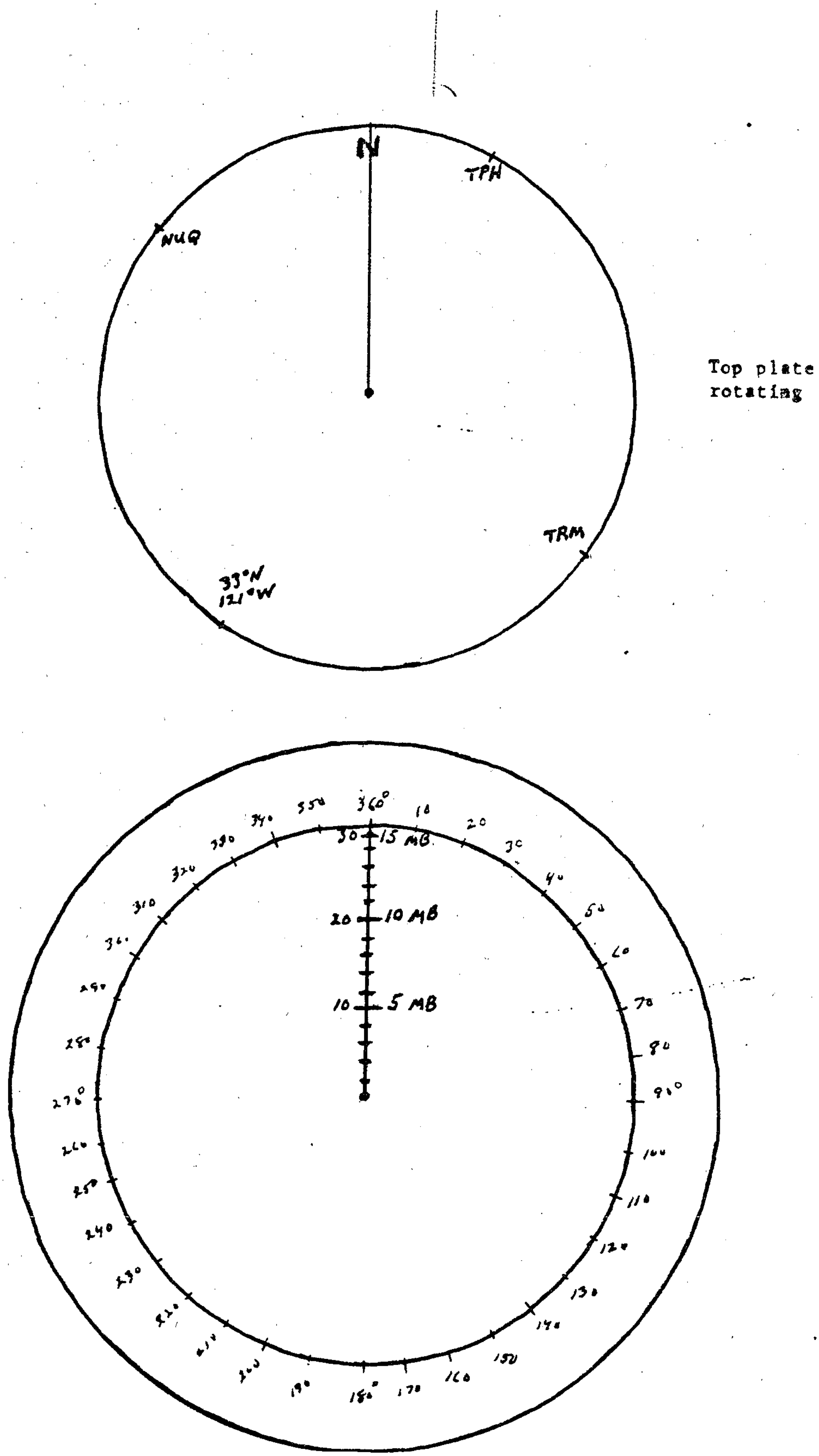

FIGURE 7. DIAGRAM OF VECTOR PLOTTING BOARD.

Western Region Technical Memoranda: (Continued)

No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189434)

No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189414)

No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189435)

No. 46 Applications of the Net Radiometer to Short-Range Fog and Stratus Forecasting at Eugene, Oregon. L. Yee and E. Bates, December 1969. (PB-190476)

No. 47 Statistical Analysis as a Flood Routing Tool. Robert J. C. Burnash, December 1969. (PB-188744)

No. 48 Tsunami. Richard A. Augulis, February 1970. (PB-190157)

No. 49 Predicting Precipitation Type. Robert J. C. Burnash and Floyd E. Hug, March 1970. (PB-190962)

No. 50 Statistical Report on Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona, 1969. Wayne S. Johnson, April 1970. (PB-191743)

No. 51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell, July 1970. (PB-193102)

No. 52 Sacramento Weather Radar Climatology. R. G. Pappas and C. M. Veliquette, July 1970. (PB-193347)

No. 53 Experimental Air Quality Forecasts in the Sacramento Valley. Norman S. Benes, August 1970. (PB-194128)

No. 54 A Refinement of the Vorticity Field to Delineate Areas of Significant Precipitation. Barry B. Aronovitch, August 1970.

No. 55 Application of the SSARR Model to a Basin Without Discharge Record. Vail Schermerhorn and Donald W. Kuehl, August 1970. (PB-194394)

No. 56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr., and Werner J. Heck, September 1970. (PB-194389)

No. 57 Preliminary Report on Agricultural Field Burning vs. Atmosphere Visibility in the Willamette Valley of Oregon. Earl M. Bates and David O. Chilcote, September 1970. (PB-194710)

No. 58 Air Pollution by Jet Aircraft at Seattle-Tacoma Airport. Wallace R. Donaldson, October 1970. (COM-71-00017)

No. 59 Application of P.E. Model Forecast Parameters to Local-Area Forecasting. Leonard W. Snellman, October 1970. (COM-71-00016)

NOAA Technical Memoranda NWS

No. 60 An Aid for Forecasting the Minimum Temperature at Medford, Oregon. Arthur W. Fritz, October 1970. (COM-71-00120)

No. 61 Relationship of Wind Velocity and Stability to SO_2 Concentrations at Salt Lake City, Utah. Werner J. Heck, January 1971. (COM-71-00232)

No. 62 Forecasting the Catalina Eddy. Arthur L. Eichelberger, February 1971. (COM-71-00223)

No. 63 700-mb Warm Air Advection as a Forecasting Tool for Montana and Northern Idaho. Norris E. Woerner, February 1971. (COM-71-00349)

No. 64 Wind and Weather Regimes at Great Falls, Montana. Warren B. Price, March 1971.

No. 65 Climate of Sacramento, California. Wilbur E. Figgins, June 1971. (COM-71-00764)

No. 66 A Preliminary Report on Correlation of ARTCC Radar Echoes and Precipitation. Wilbur K. Hall, June 1971. (COM-71-00829)

No. 67 Precipitation Detection Probabilities by Los Angeles ARTC Radars. Dennis E. Ronne, July 1971. (COM-71-00925)

No. 68 A Survey of Marine Weather Requirements. Herbert P. Benner, July 1971. (COM-71-00889)

No. 69 National Weather Service Support to Soaring Activities. Ellis Burton, August 1971. (COM-71-00956)

No. 70 Predicting Inversion Depths and Temperature Influences in the Helena Valley. David E. Olsen, October 1971. (COM-71-01037)

No. 71 Western Region Synoptic Analysis-Problems and Methods. Philip Williams, Jr., February 1972. (COM-72-10433)

No. 72 A Paradox Principle in the Prediction of Precipitation Type. Thomas J. Weitz, February 1972. (COM-72-10432)

No. 73 A Synoptic Climatology for Snowstorms in Northwestern Nevada. Bert L. Nelson, Paul M. Fransioli, and Clarence M. Sakamoto, February 1972. (COM-72-10338)

No. 74 Thunderstorms and Hail Days Probabilities in Nevada. Clarence M. Sakamoto, April 1972. (COM-72-10554)

No. 75 A Study of the Low Level Jet Stream of the San Joaquin Valley. Ronald A. Willis and Philip Williams, Jr., May 1972.

No. 76 Monthly Climatological Charts of the Behavior of Fog and Low Stratus at Los Angeles International Airport. Donald M. Gales, July 1972.

No. 77 A Study of Radar Echo Distribution in Arizona During July and August. John E. Hales, Jr., July 1972.